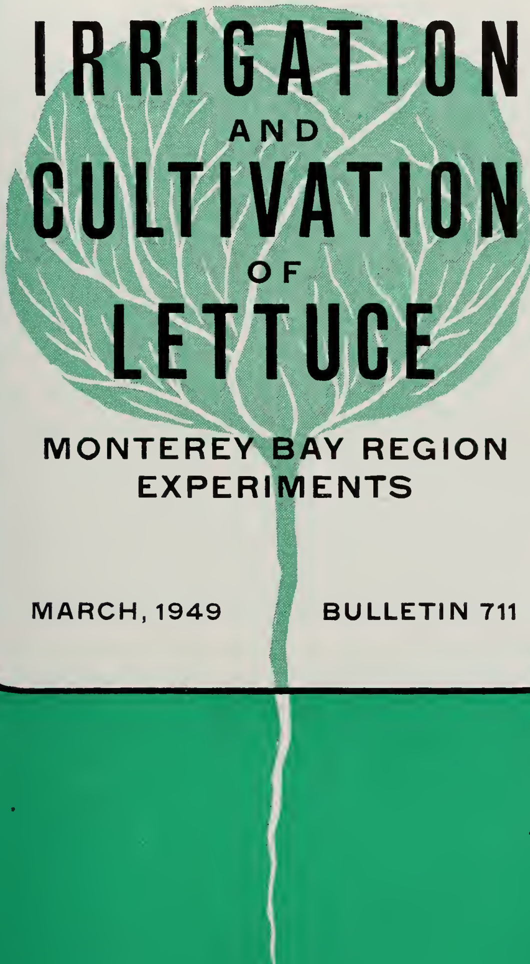
CALIFORNIA AGRICULTURAL EXPERIMENT STATION



IRRIGATION AND CULTIVATION OF LETTUCE

MONTEREY BAY REGION EXPERIMENTS

MARCH, 1949 BULLETIN 711

F. J. VEIHMEYER

A. H. HOLLAND

THE COLLEGE OF AGRICULTURE
UNIVERSITY OF CALIFORNIA • BERKELEY

The results of the experiments described in this bulletin indicate that **3 irrigations** only, **the first** to germinate the seed, **the second** at the time of thinning, and **the third** 30 days after thinning, will produce a crop without losses in yield or quality.

The results also indicate that **cultivation** after planting, other than to control weeds, is wasted effort.

THE AUTHORS

F. J. Veihmeyer is Professor of Irrigation and Irrigation Engineer in the Experiment Station.
A. H. Holland formerly Associate in the Experiment Station.

Manuscript submitted for publication April, 1948.

The Salinas and Pajaro valleys, in the Monterey Bay region of California, produce a large portion of the State's commercial lettuce.

Knott and Tavernetti (10) describe the methods used to grow head lettuce in California.

Soil Conditions and Climate

Soil conditions in this area vary greatly in texture, fertility, and drainage. Generally, however, the soils used in lettuce production range from sandy loams to clay loams. These are fertile, but often not well drained.

The climate in this area is mild throughout the year. During the summer months, cool ocean fogs blanket the valleys. Seldom is there a day when fogs are not present for at least a few hours. This has the effect of reducing plant transpiration, and evaporation from the soil surface.

Rainfall occurs almost entirely during the winter and varies greatly in amount from year to year. Rain, in appreciable amounts, is rare from May 1 to November 1.

Purpose of the Experiments

Lettuce growers in this area are not in complete agreement in their reasons for irrigation and cultivation practices, even when climatic and soil conditions are much the same.

Questions often arise as to how much water is required by lettuce. It would seem that more water is applied to the soil than is used through plant transpiration and soil-surface evaporation combined.

Information is also desired to determine the effects of different soil-moisture conditions upon growth, and whether a crop such as lettuce responds to soil moisture in the same manner as the many kinds of fruit trees, truck and field crops previously investigated at Davis (3, 4, 5, 6, 7, 8, and 17).

The reasons given for the selection of an irrigation program vary so much from grower to grower that the need for carefully planned and executed experiments is obvious.

Grower-preferences for a particular schedule of cultivation practices are also based on diverse reasons. The primary purpose, doubtless, is to destroy weeds; but other reasons are often given for tillage, such as the supposed effect on soil aeration, microbial activity, and water conservation.

One of the purposes of the experiments was to determine by careful field tests the effect of tillage on the yield of lettuce.

Effects of Soil-Moisture Conditions

Various effects upon lettuce production have been attributed to certain soil-moisture conditions.

Many growers believe that water applied to the soil when the heads are maturing is apt to make them soft and loose. They also believe that when the moisture supply is plentiful, the leaves are crisp and a lighter green than when it is at a low level. Premature production of seed stalks is sometimes believed to be due to unfavorable soil-moisture conditions.

Schwalen and Wharton (13) believe that "the highest yield of quality lettuce is produced with a uniformly high soil-moisture content throughout the season for either the winter or spring crop of lettuce in the Salt River Valley."

Knott, Andersen, and Sweet (9) remark that on New York peat soils, wide fluctuations in soil-moisture or heavy rainfall occurring as the heads mature may make them puffy. Further, they found on peat with a high water table that when the water supply was excessive, plant growth was stunted and heading was delayed and poor, although there was an absence of tipburn even in warm weather.

Tipburn and Bolting

Dearborn and Hepler (2) state that heavy applications of water in hot weather when the crop is heading will cause soft heads, tipburn, and bolting; also that withholding water will have a similar effect in relation to tipburn and bolting.

Andersen (1), working with lettuce on peat, while believing that water deficiency is the primary cause of tipburn, states: "The possibility exists that tipburn results from some physiological disorder in the plant which accompanies a reduced moisture supply to succulent tissues rather than to the reduced moisture supply itself."

Cultivation

Studies with cultivation of vegetable crops have been limited, although the principles involved seem to be well understood.

Previous cultivation experiments at Davis have shown that cultivation in the absence of weed growth does not conserve water (16), and the practice of so-called "non-cultivation of orchards" is quite common.

Thompson, Wessels and Mills (14, 15) and Doneen (3) report experiments with truck and field crops which indicate that cultivation largely benefits crops because of weed control.

GROWER IRRIGATION PRACTICES IN THE MONTEREY BAY REGION

Commercial plants of lettuce are grown on raised beds on which two rows of lettuce are planted. Occasionally a winter-grown, spring-maturing crop is planted on the flat and not irrigated.

How Beds Are Irrigated

Beds are irrigated by running water down each furrow. The general practice is to keep a small stream of water running down the furrows for many hours. When water is applied to germinate the seed, it is held in the furrow until it soaks into the beds. It is not unusual to run the water for long periods at other irrigations. However, the water is generally applied more efficiently at later irrigations.

Some growers irrigate before thinning because this practice seems to be facilitated when the soil is moist. Others irrigate after thinning because they believe irrigation helps plants recover from the disturbance of the soil caused by thinning.

Irrigation runs may vary from a few hundred to more than 1,000 feet long depending upon slope, soil type, and the practices of the individual grower.

Frequency of Irrigation

The frequency of irrigation varies considerably among growers. However, in general, irrigations are more frequent on light sandy soils than on heavy ones. In addition, sandy soils, being generally more permeable, are frequently given more water at each irrigation than are heavier soils. As many as 6 to 8 irrigations have been made on one crop. In other cases, as few as 2 or 3 irrigations have been made on crops not receiving moisture from rainfall. A fairly common practice is to irrigate a crop lightly after the first cutting has been made when 2 or 3 more cuttings are anticipated.

GROWER CULTIVATION PRACTICES

The usual tillage practices previous to planting are plowing, disking, and listing.

Sled-type implements with planters attached are then used to shape the beds (10).

Cultivation often begins shortly after the plants have two true leaves.

A more common practice is to make the first cultivation shortly before the plants are thinned.

The first cultivation is generally shallow and done with side and top knives together with shovels. The blades of the knives are so set that they will cut weeds between the two rows and on the sides of each bed. Two and four-bed tractor-powered cultivators are most commonly used.

Following the first cultivation, the beds are frequently chiseled. Two chisel-like blades are drawn through the soil to a depth of 4 to 6 inches between the two rows of each bed. After thinning, when the plants become larger, 2 to 6 cultivations are often made. These later practices may stir the soil from 1 to 3 inches deep.

LOCATION OF EXPERIMENTS

Seven irrigation experiments, 1938–39, and 5 tillage experiments, 1937–40, were conducted in the Pajaro Valley. Two irrigation experiments were conducted in the Salinas Valley in 1940.

A small area of each planted field was used. In several cases, two consecutive experimental crops were grown in the same area. Irrigation and cultural practices were under the authors' direction.

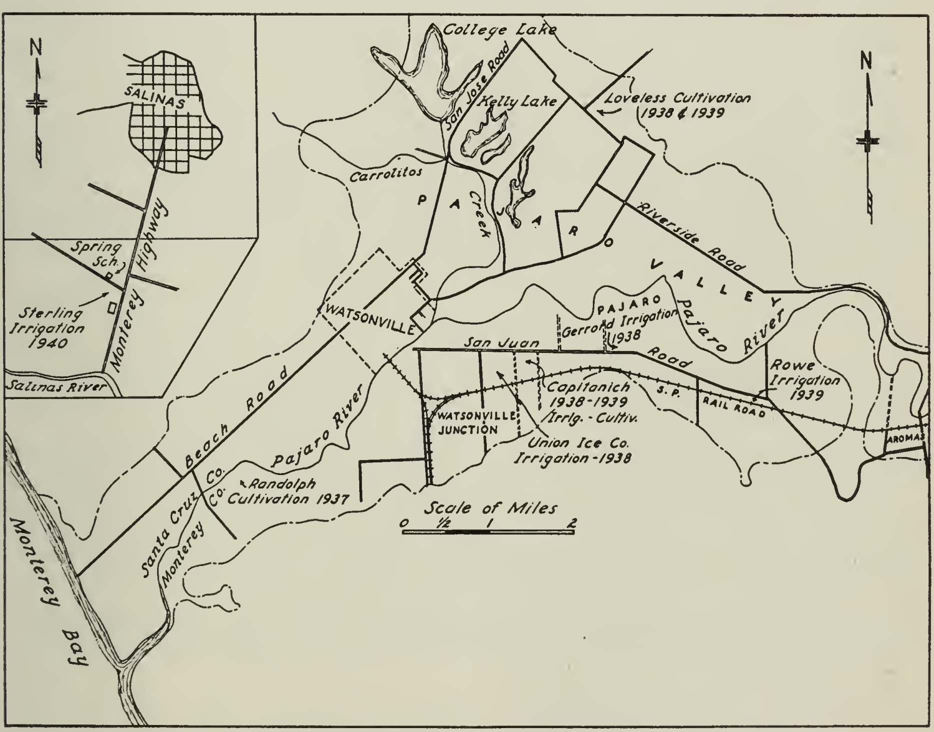


Fig. 1.—Location of irrigation and cultivation experiments in the Pajaro and Salinas valleys.

GENERAL PLAN OF THE IRRIGATION EXPERIMENTS

The general procedure was much the same in all cases.

Seed-bed preparation and planting was done by the coöperating growers as directed.

Following the usual practice, the field was plowed, disked, cultivated deeply, and then listed.

The seed was usually planted on beds about 6 inches high. Two rows were always planted on each bed. The beds were usually spaced 42 inches from center to center, and the rows on the bed were 14 inches apart. The crop was thinned so that the plants were spaced about 1 foot apart in the row.

Lettuce is designated as a spring, summer, or fall crop according to the time of maturity. In the nine irrigation experiments, 5 were summer and 4 were fall-maturing crops. All summer and 2 fall crops were planted to Imperial 847 and 2 fall crops to Imperial D lettuce.

The usual procedure used in our irrigation experiments of basing the treatments on soil-moisture conditions and not number and frequency of irrigations was found to be impracticable during the preliminary experiments of 1937. As is brought out later, it was found that the root system of lettuce in the field seemed to be such that soil-moisture samples did not give correct indications of the availability of water to the plants.

Each experiment consisted of several small plots which were given 3 to 4 treatments; that is, some experiments had 3 differential treatments while others had 4.

The treatment differences, including frequency, amount, and distribution of water applied, are discussed later in detail. Briefly stated, the treatments were designated as A, B, C, and D. Treatment A received the least number of applications, had the longest period without irrigation, and may be considered the driest plot. Treatment B received one more irrigation than A in 6 of the tests; in 2, the same number; and in 1 it received 2 more applications than did A. But in every case the length of time without irrigation was shorter than A. Treatments C and D were irrigated more frequently than either A or B. In all but one case, D received more irrigations than C. In that case it received the same number

Arrangement of plots was randomized and varied in the different experiments. Each plot usually consisted of 3 beds 50 feet long bounded on both sides by a guard bed (fig. 2).

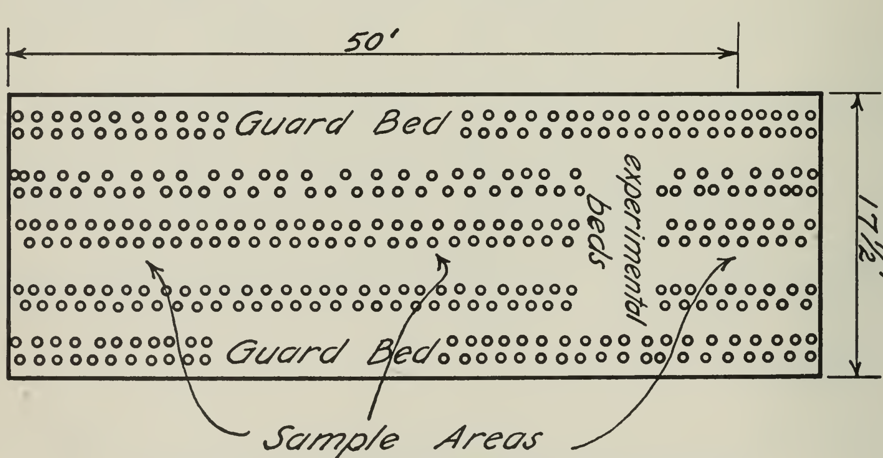


Fig. 2.—Typical arrangement of plots used in the experiments.

Experimental Irrigation Practices

The first irrigation was applied within a day or two after planting to germinate the seed.

There was one exception to this practice. One summer crop was not irrigated since rainfall wetted the soil sufficiently for seed germination.

A small stream was run down the furrows for several hours until water soaked up the sides and into the beds, finally reaching the seed. Care was taken to prevent the stream from topping the beds and washing the seed out of the soil.

By this method, the soil is wetted without causing a crust to form. Crusting might occur if the beds were flooded. Crusting of the soil before the seedling emerges is believed to be detrimental to obtaining a good stand.

Thinning

In some of our experiments we irrigated before thinning. In others, just after or not at all.

Following thinning, some plots received no further irrigation while others were irrigated once, twice, or three times. In most of these irrigations water was not allowed to cover the beds, but in some others, the beds were purposely flooded to see if flooding was harmful.

The plants were thinned 3 to 5 weeks after planting, depending upon their rate of growth.

Cultivation

One shallow but thorough cultivation was made on all crops shortly before thinning, except in the 1940 experiments.

Following thinning, the plots were furrowed and not touched by a cultivator thereafter. Weeds not destroyed by cultivation were hoed by hand.

Data Obtained

Numerous data were obtained during the experiments. These included the determination of soil-moisture, moisture equivalents, permanent wilting percentages, measurements of irrigation water, measurement of plant growth, yields, and quality. Evaporation, humidity and temperature records were obtained in the field during some of the experiments.

Measurements of Irrigation Water

In most cases irrigation water was measured at the plots with a 1-foot rectangular contracted weir.

In cases where this was not feasible, the amount of water applied was determined by timing the flow of water from the supplying pumps having rated capacities.

Moisture Determinations

Moisture determinations were made from samples gathered by a soil tube. These samples were collected at about weekly intervals during the growth of the crops.

Three samples of 6-inch increments were composited. These were taken to a depth of 3 feet on each of 2 plots for each treatment. In other words, there were 3 sampling locations at the plant and 3 in the center of the furrow (fig. 3).

The moisture determinations were made by oven drying the soil at 110° C and calculating the percentage loss on a dry weight basis.

Moisture Equivalents and Permanent Wilting Percentages

These were determined on samples collected in 1-foot increments from 2 plots of treatment A for each experiment, and composite samples were made for each of the 2 plots by collecting samples from the upper, center, and lower sections. Moisture equivalents and permanent wilting percentages are indicated for each depth of soil on the soil-moisture charts which follow.

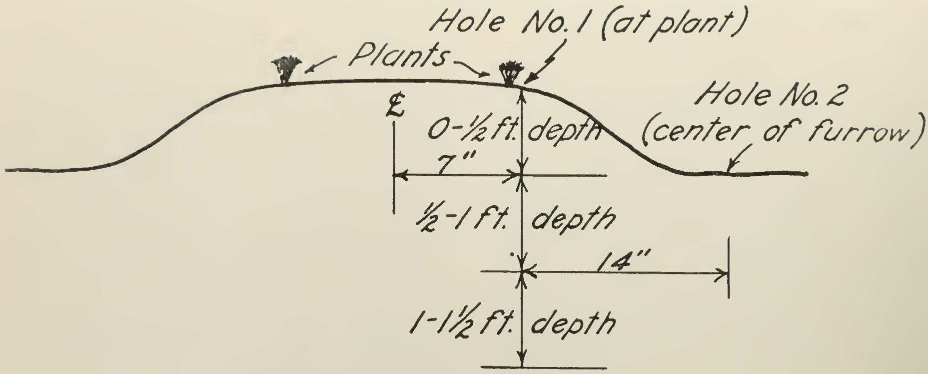


Fig. 3.—Sampling locations at the plant.

Average Weight of Plants

The average weight of about 100 plants cut at each sampling date from each treatment was used as an index of growth. Ten to 20 plants were taken at intervals of about one week from each end of all plots.

Yields

These were obtained by cutting, trimming, and weighing individually all marketable heads from each plot. Trimmings from each plot were weighed. The crops were harvested in from 2 to 5 cuttings. At the last cutting, all non-marketable plants were cut, counted, and weighed, except in 2 cases.

The areas of the plots were measured just before cutting since the original areas had been reduced by cutting plants from the plots each week.

DESCRIPTIONS OF THE IRRIGATION EXPERIMENTS

The nine irrigation experiments were designated as:

1. Union Ice Co., Summer, 1938.
2. Union Ice Co., Fall, 1938.
3. Gerrard, Summer, 1938.
4. Gerrard, Fall, 1938.
5. Capitanich, Summer, 1939.
6. Rowe, Summer, 1939.
7. Rowe, Fall, 1939.
8. Stirling, Summer, 1940.
9. Stirling, Fall, 1940.

The above names are those of the ranches on which the experiments were conducted.

The locations of these ranches have been shown in figure 1.

Union Ice Company, Summer, 1938

The plots occupied an area of about 125 by 225 feet.

The soil is classed as a Botella silty clay loam.

During the experiments, a water table stood about 3 feet from the surface. Water tables within at least 6 feet of the surface are common in the lettuce growing areas of the Pajaro and Salinas valleys.

The land had not been cultivated within 2 years previous to the experiment. This resulted in a dense sod condition. It was plowed, worked into a seed bed, planted to Imperial 847 lettuce, irrigated May 11, and thinned June 10.

Due to the clay-like nature of the surface soil throughout most of the area, the beds were extremely cloddy.

Twenty-six plots of three 50-foot experimental beds were laid out and 4 treatments of different irrigation frequencies were planned. These treatments were designated as A, B, C, and D.

Treatment A was irrigated once, at the time of planting.

Treatment B was irrigated 3 times.

Treatment C was also irrigated 3 times but at different intervals.

Treatment D was irrigated 5 times.

Dates of irrigation, amounts of water applied, and weights of lettuce plants for each treatment are shown in figure 4.

Weekly growth data were obtained by cutting and weighing 40 plants from each of 3 plots for each treatment (table 1).

The first weighings were made 4 days after the lettuce was thinned and the last about 5 weeks later.

Soil-moisture conditions for 2 plots of each treatment were determined by collecting samples at weekly intervals to a depth of 2 feet or more.

Moisture conditions at the plant (as obtained by averaging data of the 2 plots for each treatment sampled) are shown in figure 5. By the time the crop was mature, many plants had been destroyed to determine growth. No yields, therefore, were taken on those plots from which growth data were obtained.

Yield data were secured from 4 plots in treatment A; 3 plots in treatment B; 4 plots in treatment C; and 3 plots in treatment D. Table 2 gives the average yields of these plots by treatment and shows the total number of plants and marketable heads harvested.

In each experiment, all heads classed as marketable were free of disease, firm, and would probably have met minimum Federal standards for head lettuce.

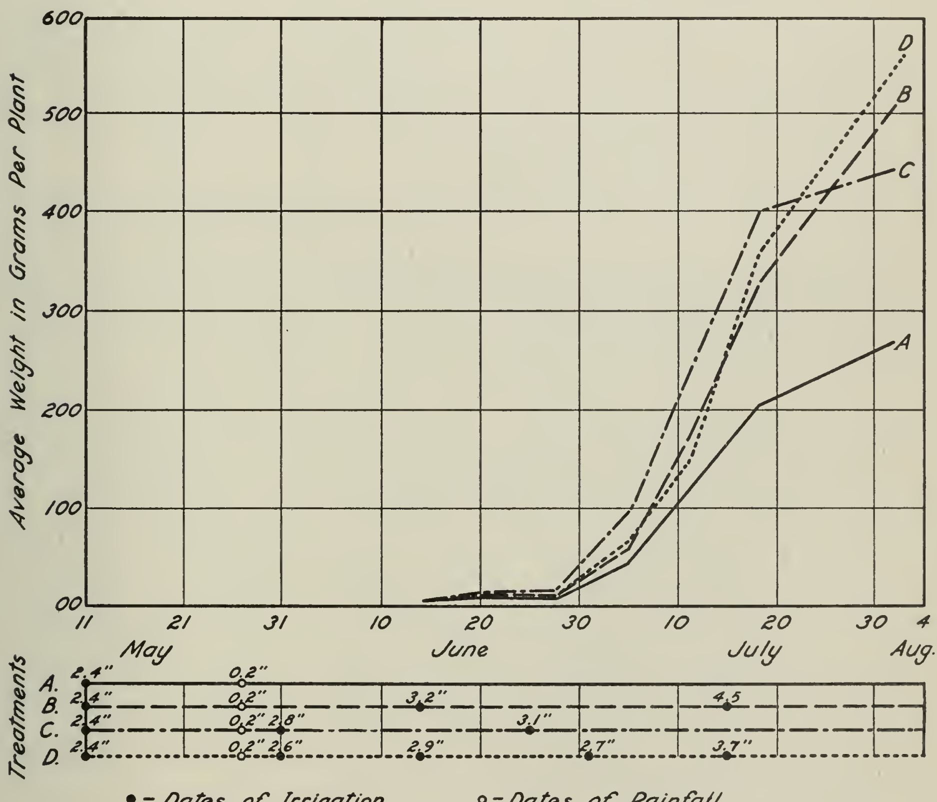


Fig. 4.—Dates of irrigation, amounts of water applied and weights of plants, Union Ice, summer, 1938.

Table 1: AVERAGE WEIGHT PER PLANT IN GRAMS, BASED ON SAMPLES OF 40 LETTUCE PLANTS PER PLOT, UNION ICE, WATSONVILLE, SUMMER 1938

Treatment	Plot	Dates Sampled						
		June 14	June 20	June 28	July 5[1]	July 11[1]	July 18[1]	Aug. 1, 2[2]
A	17	3	12	11	63	200	345	
	2	3	6	3	21	52	133	
	15	3	9	6	45	84	135	
Average....	..	3	9	7	43	112±5.3	204±9.2	281
B	13	4	13	11	72	194	405	
	19	3	7	7	36	130	212	
	12	4	8	10	59	175	355	
Average....	..	4	9	9	56	166±4.8	324±8.2	509
C	9	4	15	17	90	235	419	
	24	5	16	15	113	301	440	
	20	3	10	10	77	155	326	
Average....	..	4	14	14	93	230±6.9	395±8.6	446
D	18	3	9	12	75	178	396	
	3	2	8	8	54	117	348	
	16	4	8	8	56	150	315	
Average....	..	3	8	9	62	148±5.2	353±7.9	559

[1] The probable errors are based on weights of individual plants.
[2] Weights on August 1, 2 are the mean of the entire crop harvested for final yields. The dates represent the mean date of maturity. Mean date of maturity is discussed in detail later. This procedure of reporting data is followed in all other tables of plant weights.

Table 2: NUMBERS AND WEIGHTS OF PLANTS, UNION ICE, WATSONVILLE, SUMMER 1938

Treatment	Total plants	Average total weight per plant[3]	Lettuce per acre[1]	Marketable heads	Average weight marketable trimmed heads[2]	Marketable lettuce per acre
		grams	pounds	per cent	grams[4]	pounds
A.........	978	281±29.0	11,900	8.2	371±5.3	1,340±19
B.........	836	509±69.6	22,270	50.4	450±4.0	10,010±89
C.........	1108	446±22.9	19,660	42.1	383±2.0	7,100±37
D.........	814	559± 3.7	24,650	65.6	436±2.6	12,610±75

[1] Based on 20,000 plants per acre.
[2] Marketable heads are those cut which weighed over 300 grams.
[3] Probable errors based on average weight per plant per plot in each treatment.
[4] Probable errors are based on weights of individual heads. This applies to all tables of head weights except tables 16 and 19.

In this experiment, the minimum size was set at 300 grams, but in all other experiments reported herein, heads classed as marketable were graded in the field to be larger than 75 per standard container classification. Three hundred grams, however, is about the minimum weight for heads classified as 75 per standard container.

The crop was harvested in 3 cuttings, July 26–27, 30–31, and August 1–2. Two days were required for each cutting.

Treatment D had a significantly larger yield of marketable lettuce than the other treatments.

The yield from C was significantly larger than that from A.

The yield from B was larger than from A and C.

It should be noted that when analyzing the results of the experiments described in this bulletin, differences are considered to be significant with odds of 30 to 1. For these odds, the differences must be about 3.2 times their probable error.

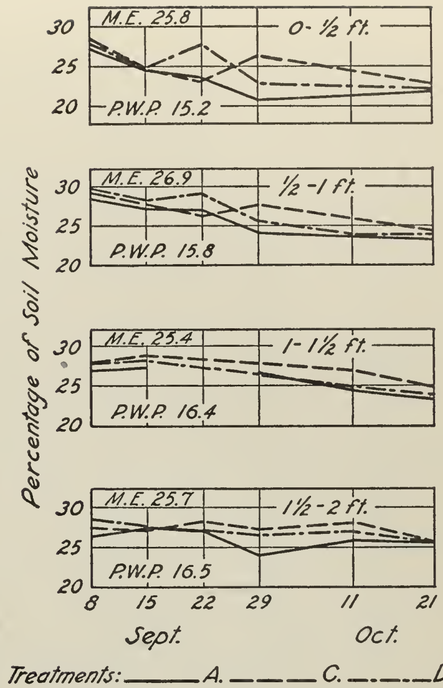


Fig. 5.—Soil-moisture conditions as determined by samples taken at the plant, Union Ice, summer, 1938. M.E. and P.W.P. are the moisture equivalent and permanent wilting percentage for each depth.

Union Ice Company, Fall, 1938

This experiment was conducted in approximately the same area as the summer experiment.

Immediately following the summer crop, the soil was disked, cultivated, ridged, planted to Imperial D lettuce, irrigated August 5 for seed germination, and thinned August 29.

Twenty-eight plots were laid out in 4 treatments (A, A-1, C, and D) of 7 plots each.

Treatment A was irrigated at the time of planting and once more 26 days later.

Treatment A-1 was irrigated the same as A. A-1 was to have been a B treatment, but a ¾ inch rainfall 58 days after planting made the proposed irrigation unnecessary.

Treatments C and D each received a third irrigation 52 and 42 days, respectively, after planting.

The dates of irrigation and amounts of water applied to each treatment are shown in figure 6.

The soil-moisture data obtained from 2 plots of A, 2 of C, and 2 of D are shown in figure 7.

Growth was determined by cutting and weighing 15 plants from each plot and calculating the average plant weight for each treatment (table 3 and fig. 6).

The crop was harvested in 3 cuttings, October 24–25, 26–27, and 28.

Yield data, including the total number of plants and marketable heads harvested for each treatment, are shown in table 4.

The yield of marketable lettuce per acre from C is greater than that from any of the other treatments.

The yield for A-1 is greater than for D or A, even though A-1 and A were irrigated the same.

The yield for D is greater than A.

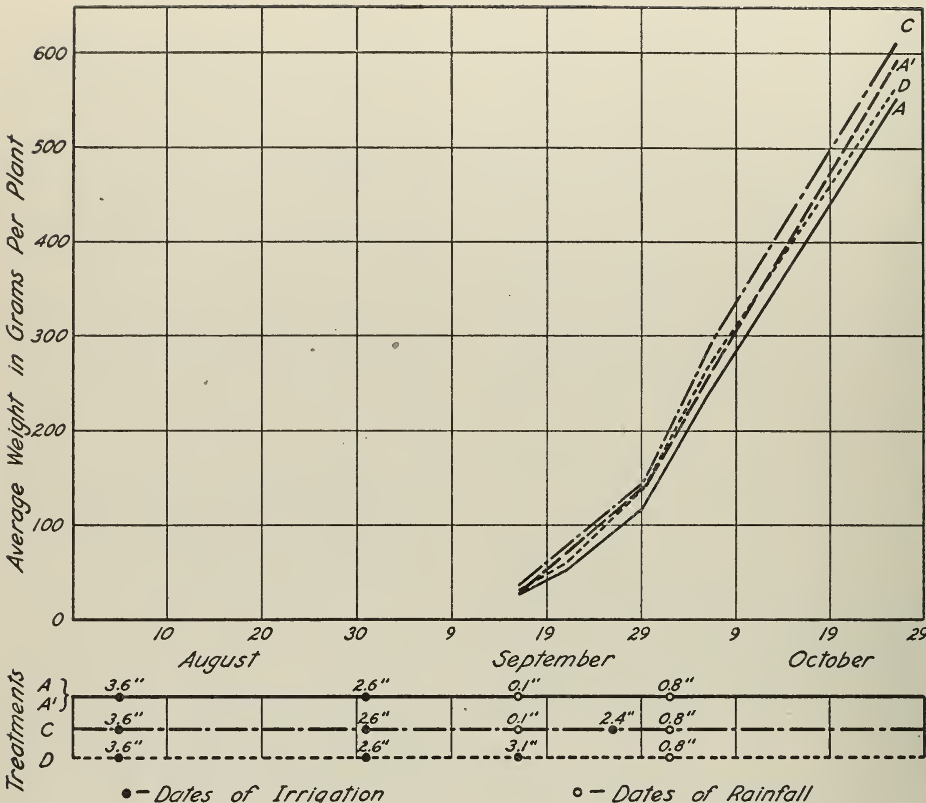


Fig. 6.—Dates of irrigation, amounts of water applied and weights of plants, Union Ice, fall, 1938.

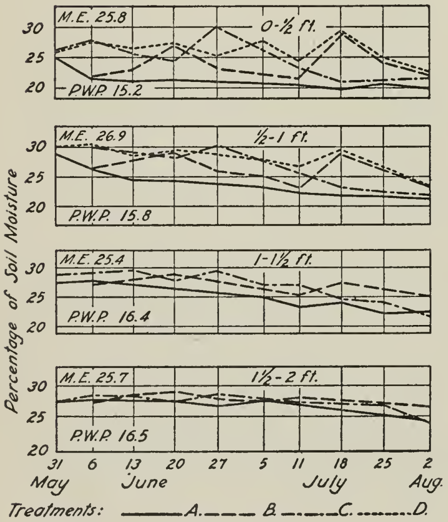


Fig. 7.—Soil-moisture conditions as determined by samples taken at the plant, Union Ice, fall, 1938. M.E. and P.W.P. are the moisture equivalent and permanent wilting percentage for each depth.

Table 3: AVERAGE WEIGHT PER PLANT IN GRAMS, BASED ON SAMPLES OF 15 LETTUCE PLANTS PER PLOT, UNION ICE, WATSONVILLE, FALL 1938

Treatment	Plot	Dates sampled				
		Sept. 16	Sept. 21	Sept. 29[1]	Oct. 7[2]	Oct. 26[3]
A	2	20	52	105	240	613
	8	22	40	96	184	499
	10	22	51	115	217	555
	15	25	48	116	225	543
	17	39	71	142	290	589
	23	22	41	117	216	509
	25	35	69	133	304	560
Average....	..	26	53	118±3.8	239±6.3	553±10.3
A′	3	25	..	132	236	594
	6	22	..	125	196	542
	12	24	..	117	221	575
	13	31	..	185	293	631
	19	27	..	118	282	557
	21	35	..	190	360	621
	28	33	..	124	234	572
Average....	..	28	..	142±5.9	260±7.9	585±8.3
C	1	19	..	158	285	616
	7	26	..	100	201	571
	9	29	..	158	324	615
	14	25	..	155	274	568
	20	39	..	128	282	638
	22	20	..	101	253	574
	24	36	..	209	404	689
Average....	..	28	..	144±6.9	289±8.0	610±11.3
D	4	20	52	110	229	505
	5	32	80	146	296	619
	11	24	44	136	224	542
	16	29	47	130	227	491
	18	31	57	149	387	553
	26	24	45	128	215	540
	27	41	96	172	296	653
Average....	..	29	60	139±4.8	268±8.2	558±15.0

[1] Probable error for Sept. 29 was determined from mean weights of 4 groups of 4 plants per plot instead of individual plants.
[2] Probable error based on weights of individual plants.
[3] Probable errors based on average weight per plant per plot in each treatment.

Table 4: NUMBERS AND WEIGHTS OF PLANTS, UNION ICE, WATSONVILLE, FALL 1938

Treatment	Total plants	Average total weight per plant[2]	Lettuce per acre[1]	Marketable heads	Average weight marketable trimmed heads[2]	Marketable lettuce per acre
		grams	pounds	per cent	grams	pounds
A......	443	553±10.3	24,380	90.5	419±2.0	16,710± 80
A'.....	517	585± 8.3	25,790	94.4	429±2.0	17,860± 83
C......	563	610±11.3	26,900	90.9	463±2.7	18,560±108
D.....	484	558±15.0	24,600	92.4	434±2.4	17,680± 98

[1] On the basis of 20,000 plants per acre.
[2] Probable errors based on average weight per plant per plot in each treatment.

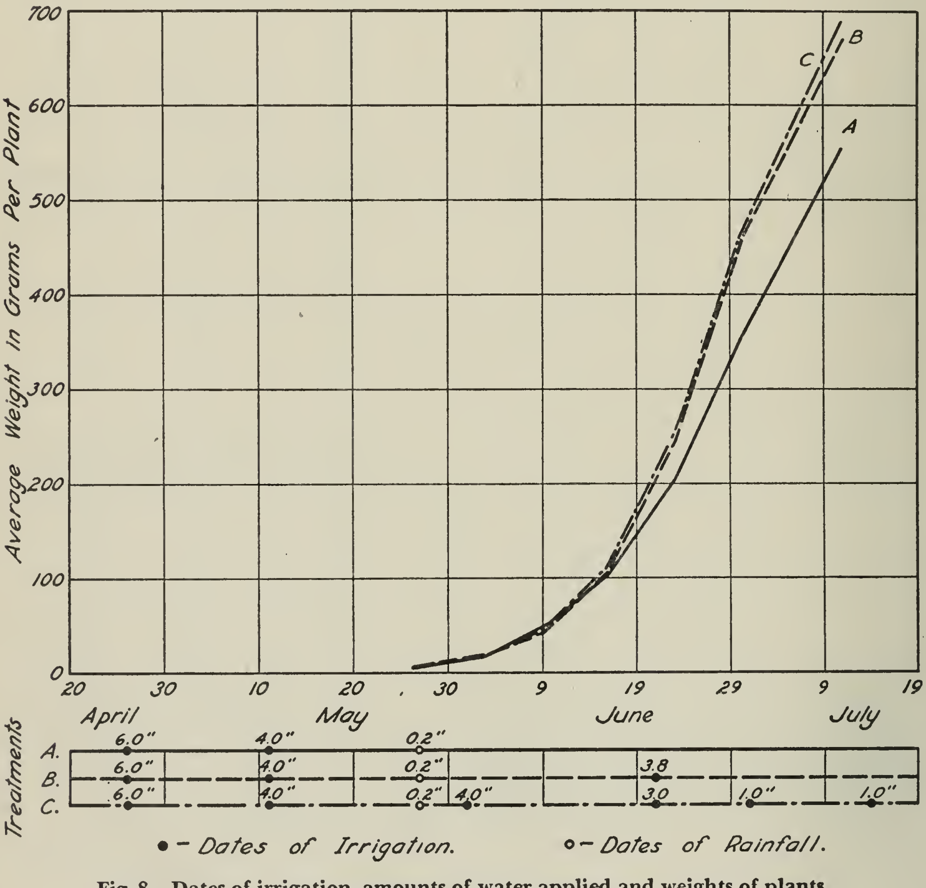


Fig. 8.—Dates of irrigation, amounts of water applied and weights of plants, Gerrard, summer, 1938.

Gerrard, Summer, 1938

These experiments were conducted on a level, rich alluvial loam of the Pajaro series. It drains slowly but had no water table within 6 feet of the surface.

On April 26, the field was planted to Imperial 847 lettuce, irrigated, and thinned May 26.

The area was divided into 6 plots of 3 treatments (A, B, and C).

Treatment A was irrigated twice, including the initial application for seed germination.

B and C were irrigated 3 and 6 times, respectively.

The dates and amounts of water applied are shown in figure 8.

Soil-moisture samples were collected from all plots. Average moisture conditions at the plant are shown for each treatment in figure 9. Soil samples for determining permanent wilting percentages were taken in 1-foot increments. These percentages are shown in figure 9.

Beginning May 26, 20 plants from each plot were cut and weighed each week. Data are shown in table 5. Average plant weights per treatment are plotted in figure 8.

The crop was harvested in 4 cuttings, July 8, 11, 14, and 18.

Yield data are presented in table 6.

The yield of marketable lettuce from C is significantly greater than that from A but not from B.

'A' yielded significantly less than the other two treatments.

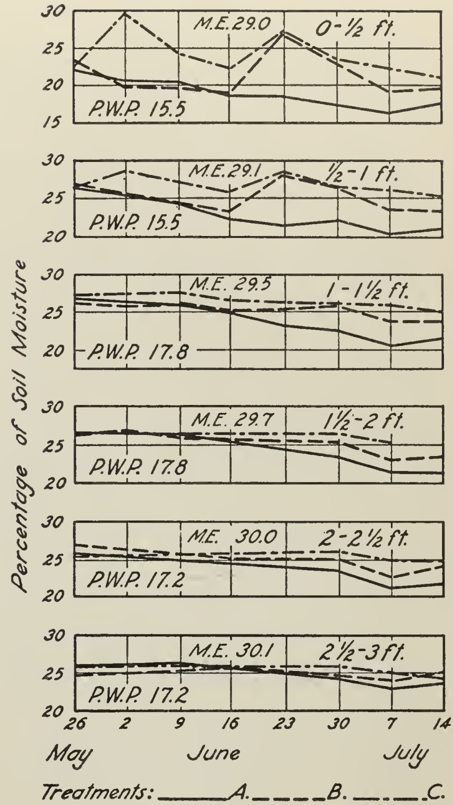


Fig. 9.—Soil-moisture conditions as determined by samples taken at the plant, Gerrard, summer, 1938.

Gerrard, Fall, 1938

This experiment was conducted on the same field as the summer one.

Imperial 847 seed was planted and irrigated August 1, and thinned August 20.

Irrigations, including rainfall, and the average weights of plants for 3 treatments (A, B, and C) are shown in figure 10.

Including the initial seed wetting, A was irrigated twice, and B and C were irrigated 3 and 5 times, respectively.

Soil-moisture conditions were determined by taking samples from 2 plots of each treatment. Figure 11 shows these conditions and the permanent wilting percentages.

Growth was measured by weekly cutting and weighing 15 plants from each plot (table 7 and figure 10).

The crop was harvested in 3 cuttings, October 14, 17, and 21.

Yields are shown in table 8.

Treatment C had significantly higher yields of marketable lettuce than A or B, and B greater than A.

Table 5: AVERAGE WEIGHT PER PLANT IN GRAMS, BASED ON SAMPLES OF 20 LETTUCE PLANTS PER PLOT, GERRARD, WATSONVILLE, SUMMER 1938

Treatment	Plot	Dates sampled						
		May 26	June 3	June 9	June 16	June 23	June 30[1]	July 12, 13
A	1	..	14	41	78	171	317	455
	6	..	18	54	127	236	384	603
Average.....	..	3	16	48	102	204±17.8	350±13.7	553[2]
B	3	..	16	37	81	211	435	640
	4	..	17	44	127	275	471	694
Average.....	..	3	17	41	104	243±10.6	453±19.1	667[2]
C	2	..	14	45	107	266	505	674
	5	..	16	47	114	257	402	700
Average.....	..	3	15	46	110	261±2.7	453±16.1	690[2]

[1] Probable errors are based on weights of individual plants.
[2] Probable errors could not be obtained from the weights taken on July 12 and 13.

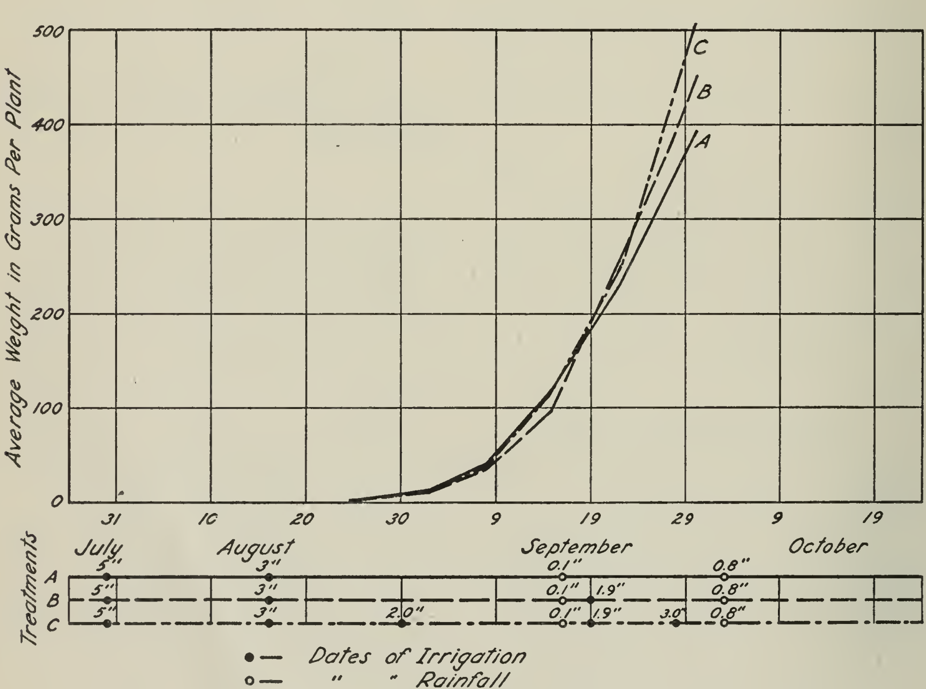


Fig. 10.—Dates of irrigation, amounts of water applied and weights of plants, Gerrard, fall, 1938.

Table 6: NUMBERS AND WEIGHTS OF PLANTS, GERRARD, WATSONVILLE, SUMMER 1938

Treatment	Total plants	Average total weight per plant	Lettuce per acre	Marketable heads	Average weight marketable trimmed heads	Marketable lettuce per acre[1]
		grams	pounds	per cent	grams	pounds
A..........	130	553	24,380	91.5	390±6.2	15,720±250
B..........	142	667	29,410	95.8	466±6.6	19,660±279
C..........	138	690	30,420	97.8	467±6.2	20,120±267

[1] Based on 20,000 plants per acre.

Table 7: AVERAGE WEIGHT PER PLANT IN GRAMS, BASED ON SAMPLES OF 15 LETTUCE PLANTS, PER PLOT, GERRARD, WATSONVILLE, FALL 1938

Treatment	Plot	Dates sampled					
		Aug. 25	Sept. 2	Sept. 8	Sept. 15	Sept. 22[1]	Sept. 30[1]
A	4	3	15	46	108	230	434
	7	2	10	35	134	237	355
Average.....	..	3	13	41	121	234±8.2	395±17.6
B	2	2	13	34	99	246	493
	5	3	14	41	100	263	411
Average.....	..	3	12	38	100	255±10.5	452±19.5
C	1	2	13	40	120	225	532
	6	3	11	43	118	249	490
Average.....	..	3	12	42	119	237±9.4	511±21.8

[1] Probable errors based on weights of individual plants.

Table 8: NUMBERS AND WEIGHTS OF PLANTS, GERRARD, WATSONVILLE, FALL 1938

Treatment	Total plants	Average weight per untrimmed marketable head	Marketable heads	Average weight marketable trimmed heads	Marketable lettuce per acre[1]
		grams	per cent	grams	pounds
A	327	755	68.8	518±4.8	15,700±146
B	277	784	69.7	547±4.5	16,800±138
C	365	764	68.2	605±5.5	18,190±165

[1] Based on 20,000 plants per acre.

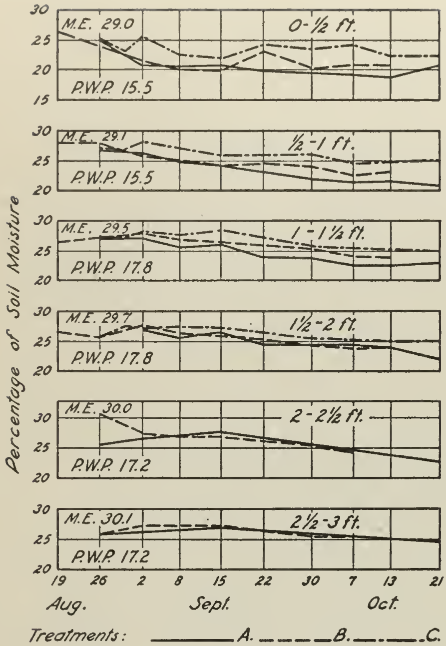


Fig. 11.—Soil-moisture conditions as determined by samples taken at the plant, Gerrard, fall, 1938. M.E. and P.W.P. are the moisture equivalent and permanent wilting percentage for each depth.

Capitanich, Summer, 1939

The soil upon which this experiment was conducted is classed as a Botella silty clay loam. It is highly productive, though a 3-foot water table was present during the experiment.

Previous to planting, the land had been cover-cropped with vetch and fertilized with 2½ tons per acre of chicken manure.

The field was planted to Imperial 847 lettuce April 22, and thinned May 30.

The area was divided into 28 plots which were given one of 4 treatments.

A received 2 irrigations, including the one at planting.

B and C received 3 irrigations.

D received 4 irrigations.

Dates of irrigation, amounts of water applied, and average weights are shown in figure 12.

Growth was determined by cutting, at approximately weekly intervals, and weighing 10 plants from each plot (table 9).

Treatment B was irrigated in the usual manner, that is by furrows without flooding the beds, but at the irrigation made on June 12, the beds were intentionally flooded. Since the beds were quite high, it was difficult to flood them, but sufficient water was applied so that the soil surface appeared sealed.

During the period June 13–19, the temperature and evaporation conditions were unusually high.

Soil-moisture conditions under the different irrigation treatments were determined by sampling from 2 plots of each treatment. These, and the permanent wilting percentages, are shown in figure 13.

The crop was harvested in 4 cuttings made July 2, 11, 14, and 17. Due to tipburn damage, there were no marketable heads harvested after the second cutting.

Yields are shown in table 10.

The yield of marketable lettuce from B is significantly higher than the others; that for D higher than from A but not from C; and from A lower than the others.

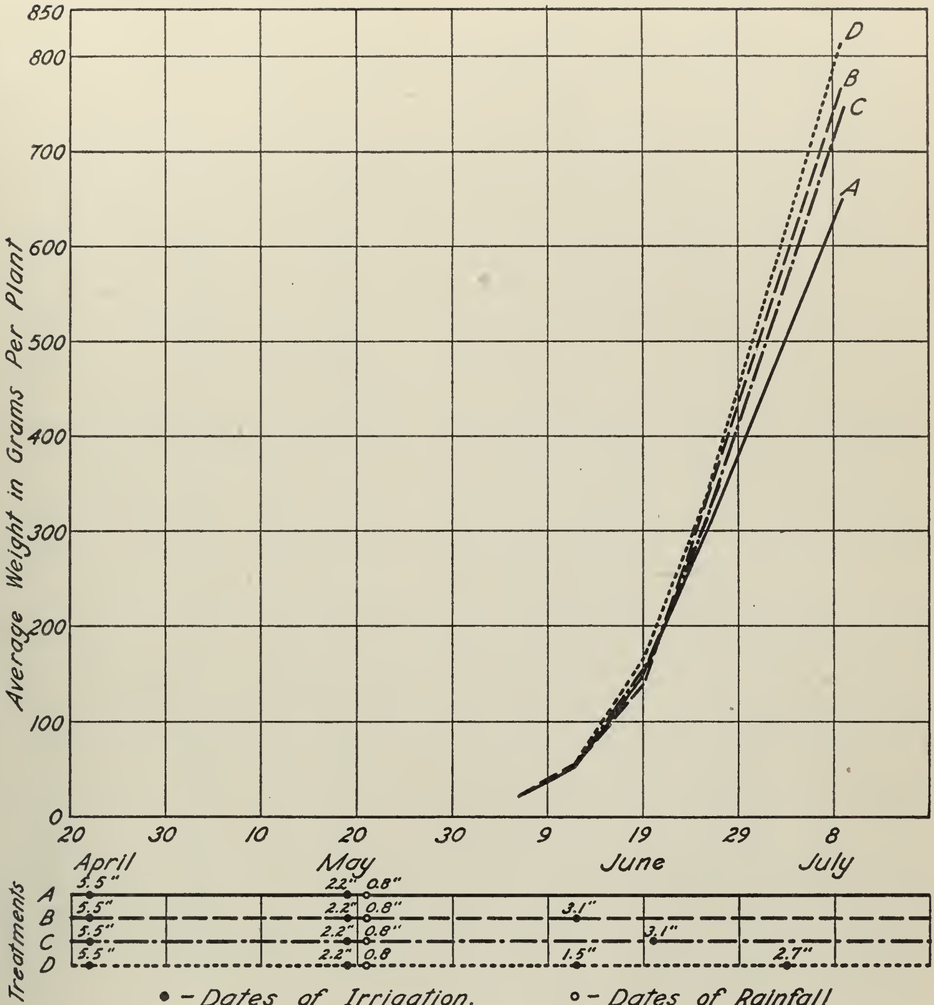


Fig. 12.—Dates of irrigation, amounts of water applied and weights of plants, Capitanich, summer, 1939.

Table 9: AVERAGE WEIGHT PER PLANT IN GRAMS, BASED ON SAMPLES OF 10 LETTUCE PLANTS PER PLOT, CAPITANICH, WATSONVILLE, SUMMER 1939

Treatment	Plot	Dates sampled				
		June 6	June 12	June 19[2]	June 26[1]	July 10
A	22	18	41	144	281	635
	2	23	53	112	288	644
	10	23	57	198	278	590
	18	19	56	137	308	640
	5	22	63	145	329	708
	20	22	55	142	301	685
	14	18	49	150	357	634
Average....	..	21	53	147±6.9	306±8.8	648
B	15	16	50	119	266	735
	23	23	48	106	275	698
	3	22	55	162	340	744
	11	22	65	159	419	848
	26	27	68	176	392	844
	13	19	52	134	349	735
	7	26	60	131	331	776
Average....	...	22	57	141±5.5	339±9.5	768
C	8	25	61	148	252	694
	16	18	47	118	263	698
	24	24	48	149	337	789
	4	23	60	150	350	826
	12	22	72	180	410	826
	27	23	56	154	350	726
	21	14	59	136	316	685
Average....	..	21	58	148±6.0	325±9.2	748
D	1	19	54	161	378	766
	9	17	49	161	349	753
	17	16	48	146	285	717
	25	23	69	183	378	894
	19	30	68	164	360	875
	6	17	54	184	330	962
	28	21	67	166	308	847
Average....	..	20	58	166±4.0	341±9.8	831

[1] Probable error based on weights of individual plants.
[2] Probable error based on average of two groups of 5 plants for each of 7 plots per treatment.

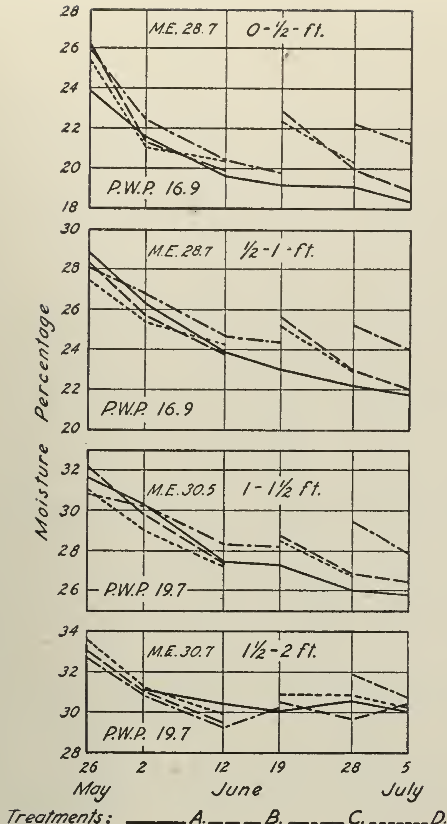


Fig. 13.—Soil-moisture conditions as determined by samples taken at the plant, Capitanich, summer, 1939. M.E. and P.W.P. are the moisture equivalent and permanent wilting percentage for each depth.

Rowe, Summer, 1939

These experiments were conducted on soil classed as Elder loam. It is deep and well drained. Imperial 847 lettuce was planted and irrigated May 11. Since the beds were quite high and not completely wetted by the first irrigation, a second irrigation was made May 20. Thinning was done June 5. Twelve plots were laid out into 3 treatments (A, B, and C). All plots were irrigated 4 days before thinning.

After thinning, A was irrigated once and all beds flooded, water covering the top of the beds. The beds in B and C were not flooded. B was given one irrigation, but later than A. C was irrigated twice. Dates of irrigation, amounts of water applied, and average weights of plants are shown in figure 14.

Growth data were obtained by weekly cutting and weighing 25 plants for each plot (table 11).

Soil-moisture conditions were obtained by weekly sampling from 2 plots of each treatment. These conditions and the permanent wilting percentages are shown in figure 15.

Yields were obtained from 3 cuttings made July 22, 25, and 28 (table 12).

The yield of marketable lettuce from treatment C is significantly greater than for A or B, and that from B is greater than from A.

Table 10: NUMBERS AND WEIGHTS OF PLANTS, CAPITANICH, WATSONVILLE, SUMMER 1939

Treatment	Total plants	Average total weight per plant[1]	Lettuce per acre[2]	Marketable heads	Average weight marketable trimmed heads	Marketable lettuce per acre
		grams	pounds	per cent	grams	pounds
A	1563	648± 9.8	28,570	47.6	509± 9.3	10,670±195
B	1597	769±14.7	33,910	69.8	561±10.7	17,240±329
C	1716	749±16.0	33,030	63.5	542± 8.8	15,170±246
D	1611	831±22.5	36,640	58.9	590±13.3	15,320±345

[1] Probable errors based on average plant weights per plot in each treatment.
[2] Based on 20,000 plants per acre.

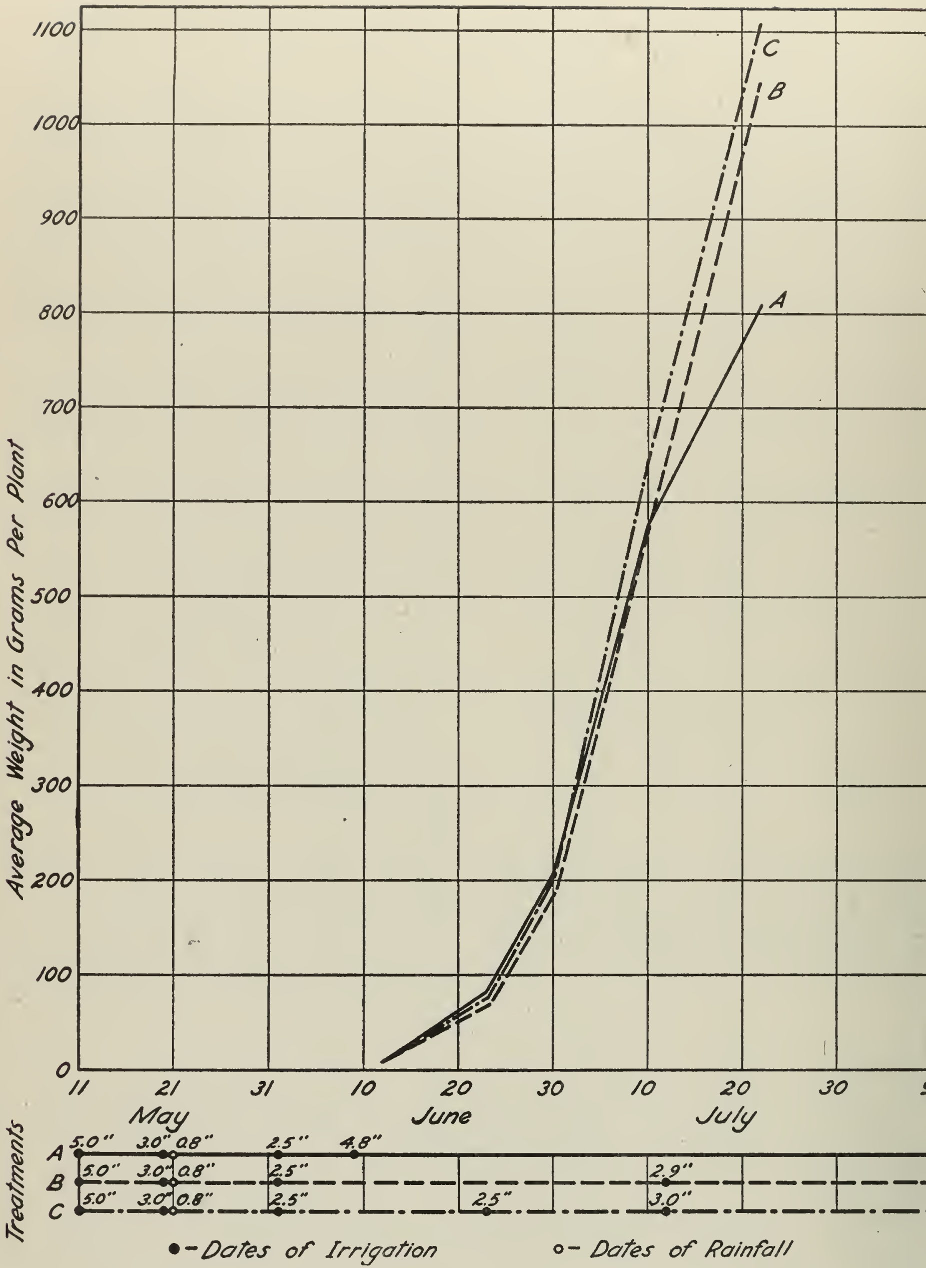


Fig. 14.—Dates of irrigation, amounts of water applied and weights of plants, Rowe, summer, 1939.

Table 11: AVERAGE WEIGHT PER PLANT IN GRAMS, BASED ON SAMPLES OF 25 LETTUCE PLANTS PER PLOT, ROWE, WATSONVILLE, SUMMER 1939

Treatment	Plot	Dates sampled				
		June 12	June 23	June 30[1]	July 10[1]	July 23, 24
A	1	7	82	213	593	840
	4	9	76	210	654	896
	9	11	89	221	540	717
	12	7	82	186	511	803
Average....	..	9	82	208±1.4	575±11.6	814
B	2	7	69	193	614	1055
	5	7	70	178	566	1085
	7	8	76	223	571	1003
	10	8	62	147	543	1040
Average....	..	7	69	185±5.0	573±11.3	1046
C	3	8	90	222	659	1097
	6	8	65	174	636	1151
	8	9	87	231	697	1109
	11	8	70	178	578	1063
Average....	..	8	78	201±4.9	643±11.1	1105

[1] Probable errors based on weights of individual plants.

Table 12: NUMBERS AND WEIGHTS OF PLANTS, ROWE, WATSONVILLE, SUMMER 1939

Treatment	Total plants	Average total weight per plant[1]	Lettuce per acre[2]	Marketable heads	Average weight marketable trimmed heads	Marketable lettuce per acre
		grams	pounds	per cent	grams	pounds
A	1137	814±25.4	35,890	76.0	631±2.7	21,160± 90
B	1083	1046±11.5	46,120	80.7	771±3.2	27,420±114
C	1106	1105±23.0	48,720	86.9	817±3.2	31,300±123

[1] Probable errors based on average plant weight per plot in each treatment.
[2] Based on 20,000 plants per acre.

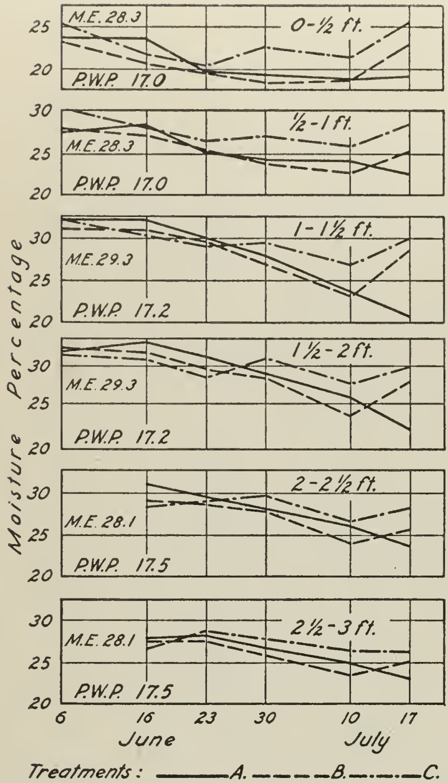


Fig. 15.—Soil-moisture conditions as determined by samples taken at the plant, Rowe, summer, 1939. M.E. and P.W.P. are the moisture equivalent and permanent wilting percentage of each plant.

Rowe, Fall, 1939

This experiment, made in the same field as the summer experiment, and with the same lettuce, was given 3 treatments (A, B, and C).

It required two irrigations to wet the beds for seed germination, one on August 9, the date of planting, and the other on August 19. A second irrigation probably would have been unnecessary if the soil had been thoroughly wetted at the first irrigation.

A third irrigation was made September 8 to all plots. They were thinned September 12.

Treatment A received one more irrigation, 44 days after planting.

B also received one more irrigation, but it was 63 days after planting.

It took 91 days before any heads were ready for harvest, a longer period than that for any other crop during the irrigation experiments.

Irrigations were made in the usual manner except for the last application of the A and B treatments. In these, the entire beds were quickly flooded by submerging them with a large stream of water.

Dates of irrigation and amounts of water used are shown in figure 16.

Growth was determined by weighing 20 plants from each plot (fig. 16 and table 13).

During the period September 14–26, the temperature and evaporation conditions were extremely high.

Moisture determinations were made on soil samples from 2 plots of each treatment. These, and the permanent wilting percentages for the summer crop (also used for the fall crop), are shown in figure 17.

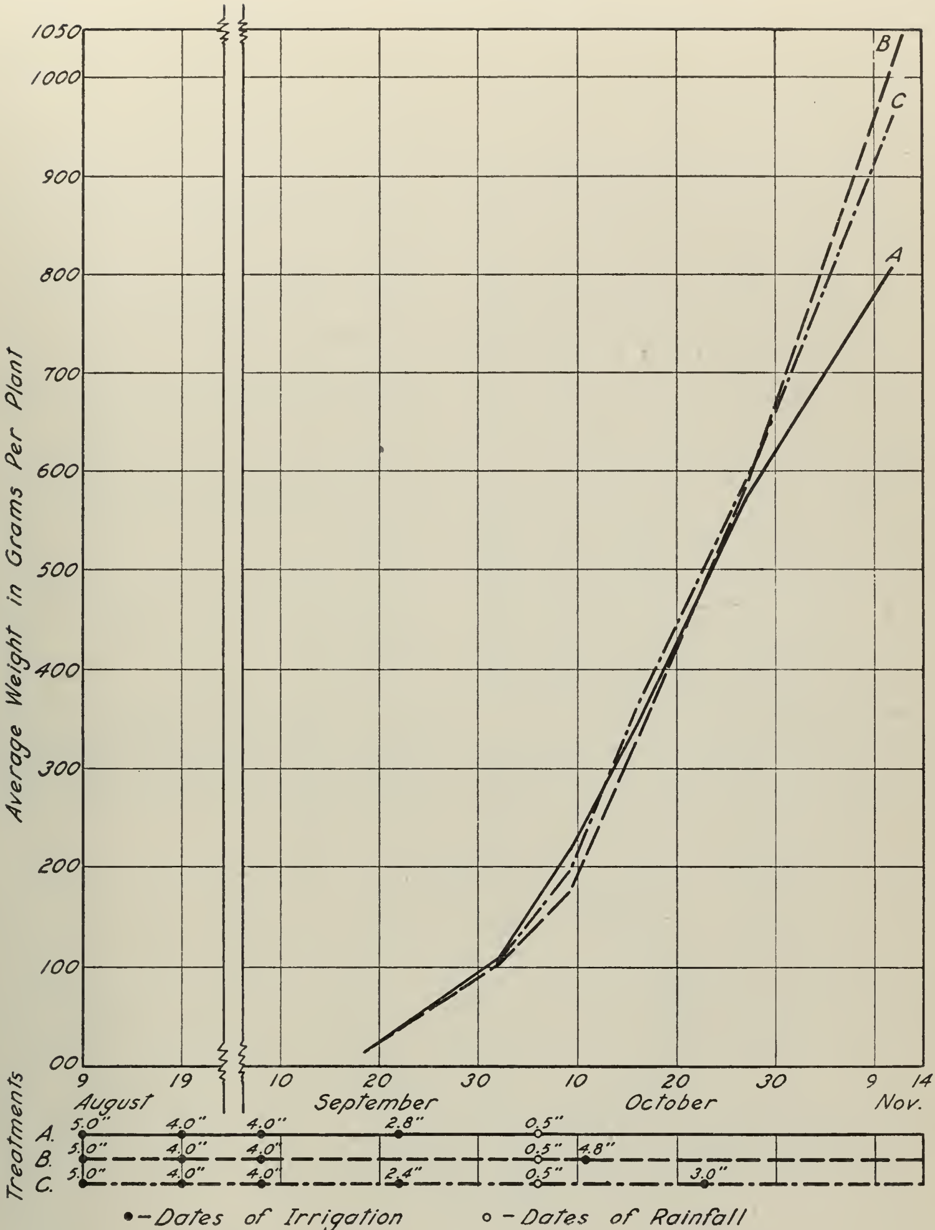


Fig. 16.—Dates of irrigation, amounts of water applied and weights of plants, Rowe, fall, 1939.

Three cuttings were made: the first on November 8, 9, and 10, the second on November 14, and the last on November 17. Yields are given in Table 14.

The yield of marketable lettuce is significantly greater for C than for B but not for A, and that for A is greater than that for B.

Shortly before the crop was harvested, a ditch was dug across a bed in treatment A so that the face bisected the tap root of a lettuce plant. The face was marked off into twenty-four 2-inch squares from which a sample of soil was taken by cutting 2 inches into the face.

After obtaining the moisture losses from the 2-inch cube samples, they were screened through a 2-millimeter screen. The weight of the soil particles larger than 2 millimeters was subtracted from the wet and dry weights of the respective samples, and moisture determinations were determined on that basis.

Moisture equivalents were determined on the screened samples. Using the data for the moisture equivalent and permanent wilting percentage determinations made for the experiment, the average

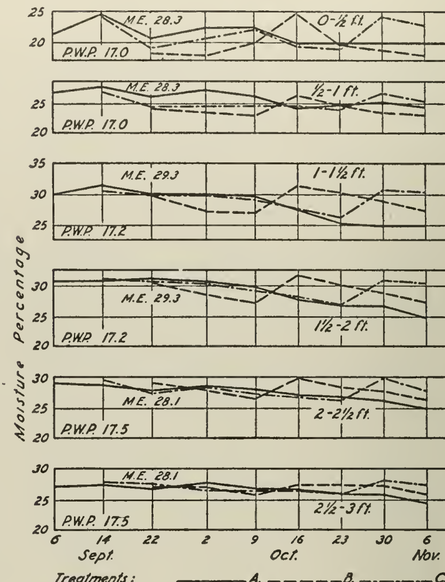


Fig. 17.—Soil-moisture conditions as determined by samples taken at the plant, Rowe, fall, 1939. M.E. and P.W.P. are the moisture equivalent and permanent wilting percentage of each plant.

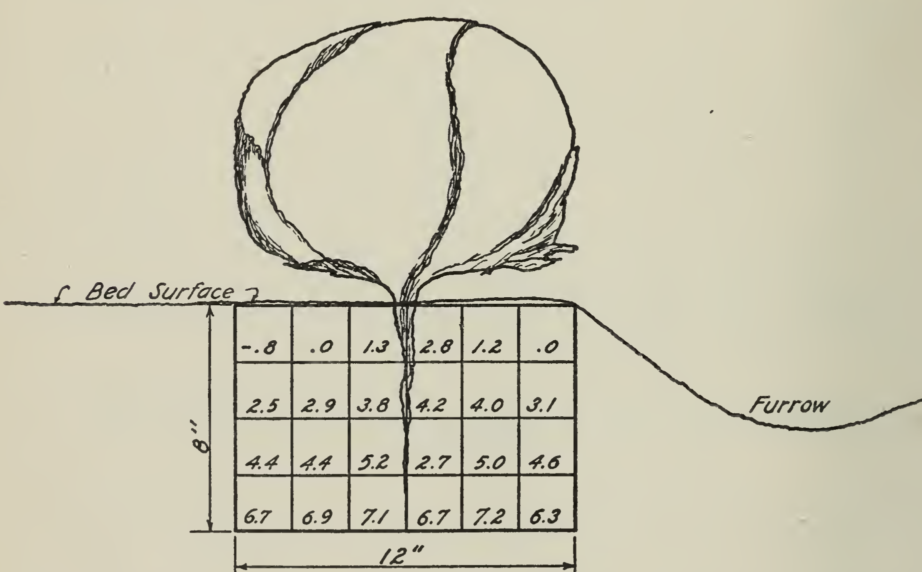


Fig. 18.—Distribution of moisture under a lettuce plant 35 days after irrigation in treatment A. The values are the percentages of moisture above the permanent wilting percentage, and in one case below this percentage as is indicated by the minus sign.

Table 13: AVERAGE WEIGHT PER PLANT IN GRAMS BASED ON SAMPLES OF 20 LETTUCE PLANTS PER PLOT, ROWE, WATSONVILLE, FALL 1939

Treatment	Plot	Dates sampled					
		Sept. 19	Oct. 2	Oct. 9[1]	Oct. 16[1]	Oct. 27[1]	Nov. 11[2]
A	1	10	86	159	260	509	
	4	13	111	208	381	661	
	6	16	108	219	386	716	
	10	14	114	225	323	480	
	12	21	117	235	415	605	
	16	14	104	215	312	456	
	19	16	112	213	343	613	
Average......	..	15	107	211±16.8	346±8.0	577±12.5	809
B	2	12	82	156	262	511	(Nov. 12)[2]
	5	15	111	209	418	801	
	8	12	87	145	280	538	
	11	16	112	226	405	695	
	14	13	120	131	282	441	
	17	18	102	188	317	497	
	20	18	110	162	342	595	
Average......	..	15	104	174±6.1	329±8.7	583±11.6	1045
C	3	12	98	176	364	562	(Nov. 11)[2]
	7	13	103	232	347	619	
	9	12	97	181	360	581	
	13	14	111	228	355	561	
	15	14	96	182	344	636	
	18	16	128	209	413	638	
	21	15	98	156	315	527	
Average......	..	14	104	195±4.9	357±7.0	589±10.8	961

[1] Probable errors based on weights of individual plants.
[2] Probable errors could not be obtained from the weights taken on Nov. 11 and 12.

Table 14: NUMBERS AND WEIGHTS OF PLANTS, ROWE, WATSONVILLE, FALL 1939

Treatment	Total plants	Average weight per untrimmed marketable head[1]	Marketable heads	Average weight marketable trimmed heads	Marketable lettuce per acre[2]
		grams	per cent	grams	pounds
A	1170	863±24.1	79.8	503±4.5	17,720±158
B	1156	828±27.4	65.0	484±4.6	13,930±132
C	1342	868±16.2	77.1	537±4.9	18,430±166

[1] Probable errors based on average plant weights per plot in each treatment.
[2] Based on 20,000 plants per acre.

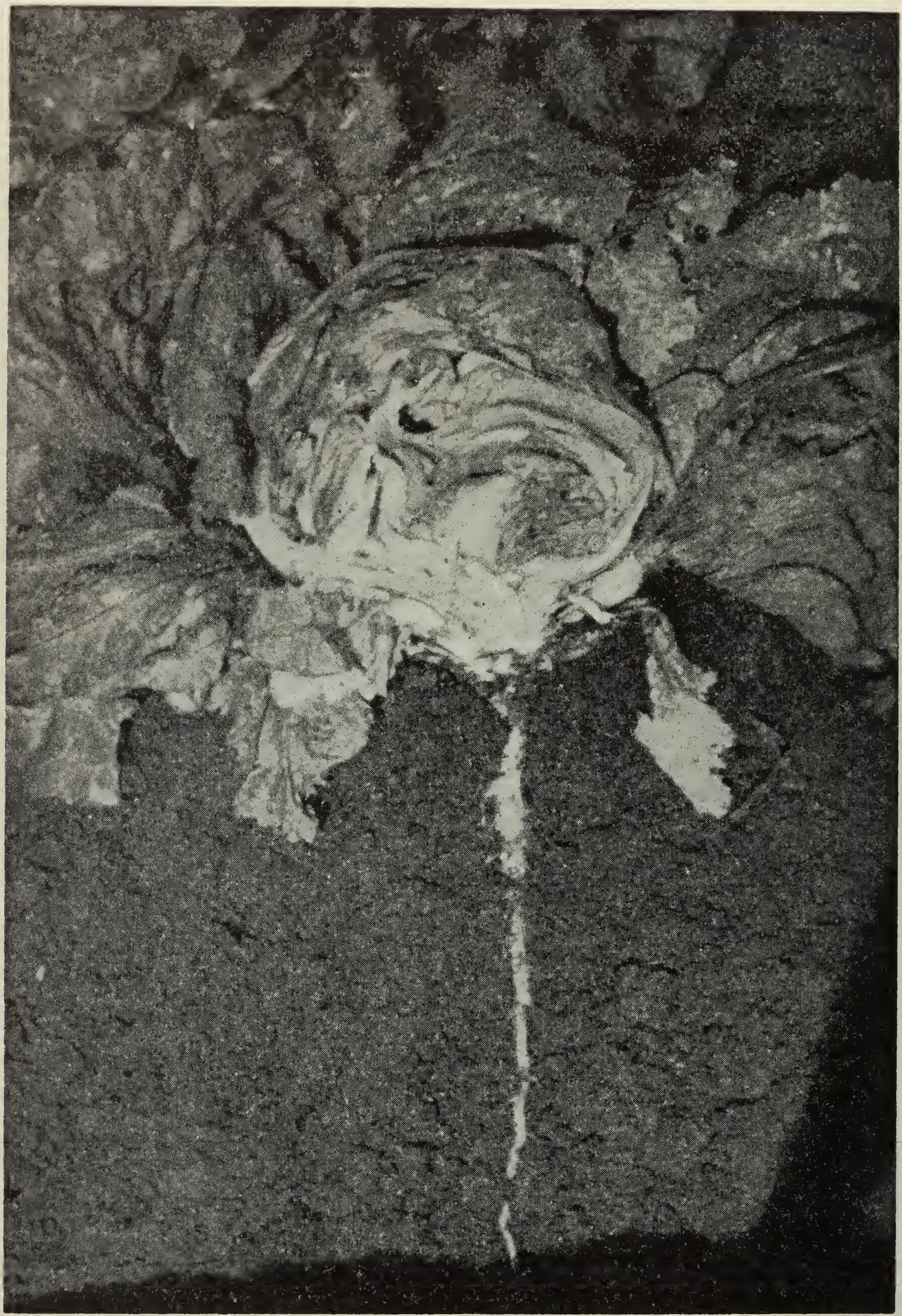


Fig. 19.—The sparse root development of lettuce. Photograph of face of trench cut across a bed at time of harvest. The absence of lateral roots and large masses of soil not occupied by roots is evident.

ratio of permanent wilting percentages to moisture equivalents was found to be 0.60. This indicates that 60 per cent of the total water held by that soil is not readily available to the plant. With this knowledge, the per cent of available moisture remaining in each soil sample was calculated. These percentages, shown in their respective locations from the plant (figure 18), are the moisture contents in percentages above the permanent wilting percentage. The indication is that moisture was available for plant use except in areas of the surface 2 inches of soil.

The sparse root development of lettuce under the conditions of these experiments is further shown in figure 19.

Stirling, Summer, 1940

This experiment was made on a field which had been winter cover-cropped to vetch.

The soil is a Salinas silty clay loam, and drains quite rapidly, although during the experiment, the water table remained within 3 to 4 feet of the surface.

The crop was planted April 7 to Imperial 847 and was thinned May 1. No irrigation was necessary to germinate the seed because the soil was already moistened by spring rains.

The area was divided into 4 treatments (A, B, C, and D) of 10 plots each, with relatively low beds, 4 or 5 inches high.

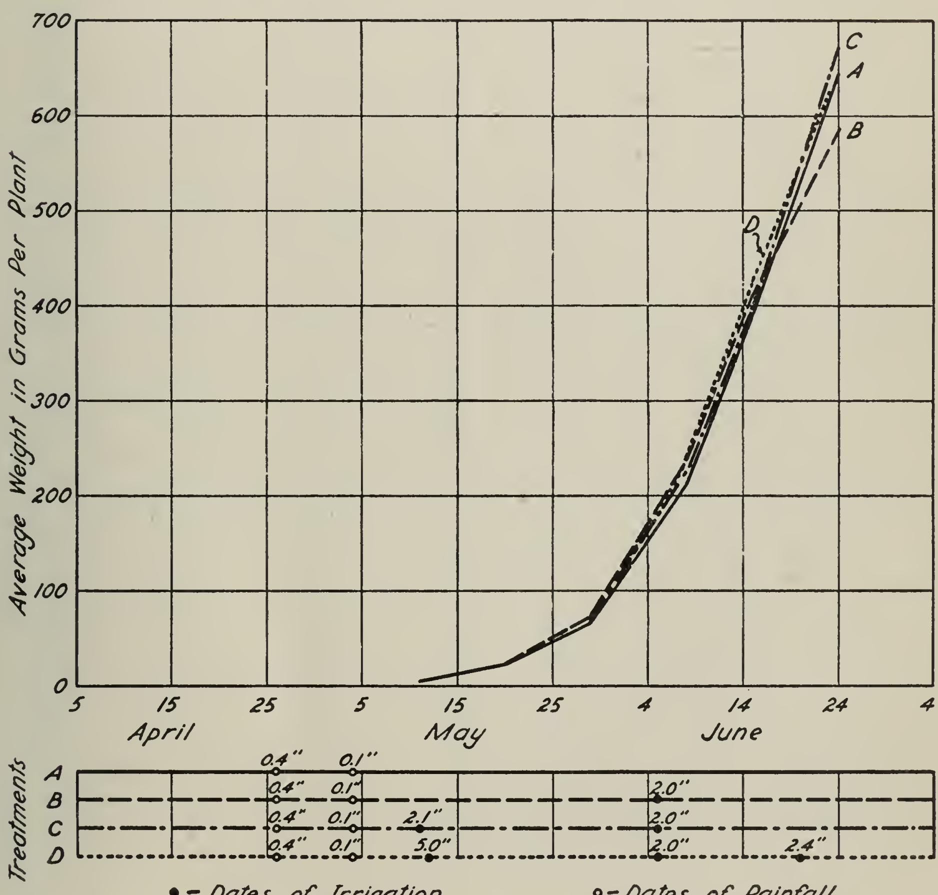


Fig. 20.—Dates of irrigation, amounts of water applied and weights of plants, Stirling, summer, 1940.

Table 15: AVERAGE WEIGHT PER PLANT IN GRAMS, BASED ON SAMPLES OF 10 LETTUCE PLANTS PER PLOT, STIRLING, SALINAS, SUMMER 1940

Treatment	Plot	Dates sampled					
		May 11	May 20	May 29	June 8[1]	June 15[1]	June 24, 25
A	1	7	23	88	243	509	615
	5	5	29	76	225	426	642
	17	6	22	81	197	411	642
	19	4	15	46	186	355	624
	23	5	24	60	186	424	689
	26	6	27	90	309	348	674
	29	4	18	50	192	328	655
	33	6	24	64	196	380	646
	37	6	21	70	217	391	633
	40	4	19	59	175	365	604
Average...	..	5	22	68	213±5.6	394±10.6	642
B	2	7	28	40	274	510	633
	6	4	22	34	240	447	688
	8	6	24	37	246	389	595
	10	4	20	36	235	375	542
	11	4	24	72	273	444	611
	20	6	23	61	207	351	558
	22	5	22	72	237	482	551
	24	5	18	64	189	336	566
	28	5	22	52	226	350	598
	35	4	18	49	182	326	557
Average...	..	5	22	52	231±6.2	410±9.9	590
C	4	5	30	74	278	412	697
	9	5	26	61	211	337	701
	12	5	20	68	191	426	696
	14	3	19	73	264	385	641
	16	5	22	83	250	415	700
	18	5	19	60	176	327	645
	25	4	21	56	207	408	596
	27	6	23	92	266	478	670
	31	4	25	66	226	403	699
	39	5	23	64	188	466	673
Average...	..	5	23	70	226±5.9	406±11.4	672
D	3	6	22	97	253	420	616
	7	5	27	58	278	460	615
	13	5	24	80	237	366	674
	15	5	21	58	183	419	598
	21	6	22	62	249	503	626
	30	5	18	56	189	314	580
	32	5	25	79	283	460	643
	34	5	21	50	187	387	602
	36	6	29	77	215	486	681
	38	4	32	72	242	442	635
Average...	..	5	24	69	232±5.7	426±10.6	627

[1] Probable errors based on weights of individual plants.

Treatment A received no irrigation.

B, C, and D received 1, 2, and 3 irrigations, respectively.

Irrigations on the B and C plots were made by lightly flooding and submerging the entire beds. Other irrigations were made in the usual manner.

Plant weight data are shown in table 15, and figure 20 shows the dates of irrigation, amounts of water applied, dates of rainfall, and the average weights of plants.

Weekly soil-moisture determinations made on samples from 2 plots of each treatment, and permanent wilting percentages are shown in figure 21.

Yields were obtained in 5 cuttings. These were made June 18, 22, 25, 29, and July 5.

Yields are shown in Table 16.

The largest yield of marketable lettuce is from treatment C, but it is not significantly greater than the yield from A.

The second largest yield, that from A, is significantly larger than from B and D, and that from C is significantly larger than from B.

On June 22, date of the second cutting, five trimmed and five untrimmed heads were cut from one plot in A, C, and D. Individual heads were weighed, dried at 70°C, and the moisture contents determined on a fresh weight basis (table 17).

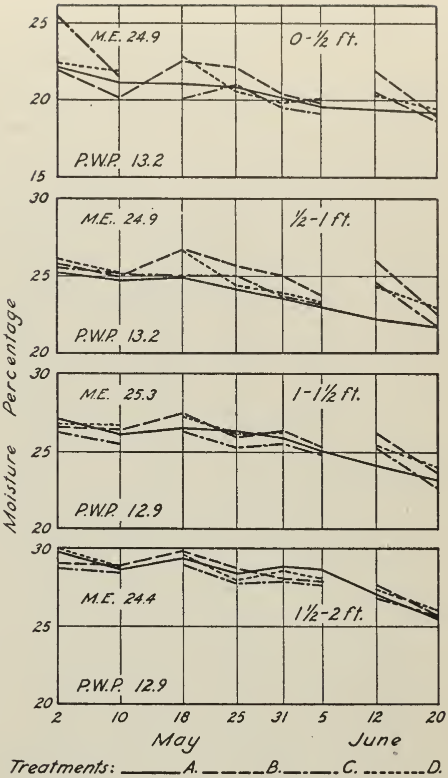


Fig. 21.—Soil-moisture conditions as determined by samples taken at the plant, Stirling, summer, 1940. M.E. and P.W.P. are the moisture equivalent and permanent wilting percentage for each plant.

Table 16: NUMBERS AND WEIGHTS OF PLANTS, STIRLING, SALINAS, SUMMER 1940

Treatment	Total plants	Average total weight per plant[1]	Lettuce per acre[3]	Marketable heads	Average weight marketable trimmed heads[2]	Marketable lettuce per acre[3]
		grams	pounds	per cent	grams	pounds
A..........	1988	642±5.5	28,300	88.9	430±2.8	16,840±110
B..........	1803	590±9.7	26,010	83.9	401±6.0	14,820±222
C..........	1859	672±7.4	29,630	88.6	445±4.7	17,390±184
D..........	2031	627±7.1	27,650	86.4	426±3.5	16,220±133

[1] Probable errors based on average plant weights per plot for each treatment.
[2] Probable errors are based on the 10 plot average for each treatment. In all tables except tables 16 and 19 the probable errors for marketable heads are based on individual weights of heads.
[3] Based on 20,000 plants per acre.

Table 17: MOISTURE IN LETTUCE HEADS, HARVESTED JUNE 22, 76 DAYS AFTER PLANTING, STIRLING, SALINAS, SUMMER 1940

Plot and treatment					
A		C[1]		D[2]	
Untrimmed heads	Trimmed heads	Untrimmed heads	Trimmed heads	Untrimmed heads	Trimmed heads
per cent	per cent	per cent	per cent	per cent	per cent
95.4	95.4	96.0	96.8	94.5	96.4
95.6	96.1	95.5	96.9	96.2	96.6
95.7	95.8	95.3	97.0	95.4	96.8
94.3	96.4	96.2	97.2	95.2	96.6
95.7	97.4	95.6	97.1	96.5	96.6
Average 95.3	96.2	95.7	97.0	95.6	96.6

[1] Harvested 17 days after irrigation. [2] Harvested 2 days after irrigation.

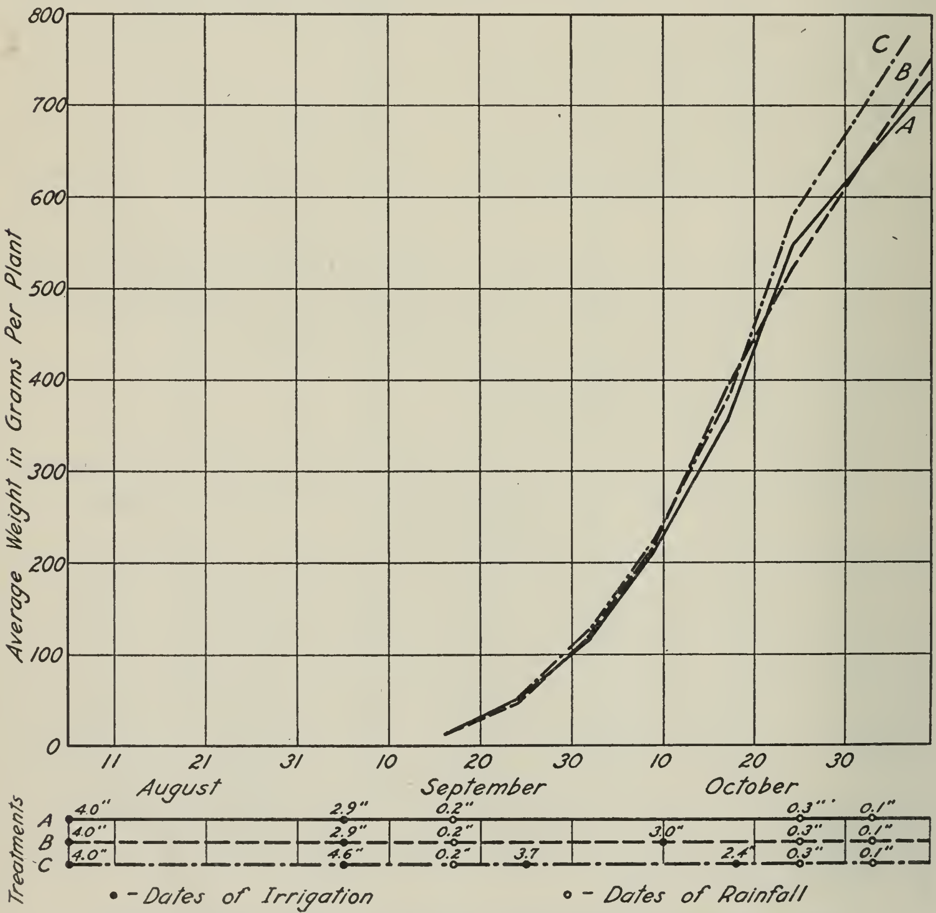


Fig. 22.—Dates of irrigation, amounts of water applied and weights of plants, Stirling, fall, 1940.

Stirling, Fall, 1940

This experiment was conducted in the same field as the summer experiment.

The crop was planted to Imperial D lettuce and irrigated August 6. Plants were thinned September 9.

Twenty-nine plots were laid out in 3 treatments (A, B, and C). All treatments were irrigated at planting and shortly before thinning. A received no further irrigation. B and C received 1 and 2 irrigations, respectively, after thinning.

After the initial seed-wetting irrigation, A and B were irrigated so that the entire beds were flooded and submerged.

C was irrigated in the usual manner.

Dates of irrigation, amounts of water, and average weights of plants obtained by weekly cutting and weighing 10 plants from each plot, are shown in figure 22.

Table 18 gives the weight of plants by plot at various times during the growing period.

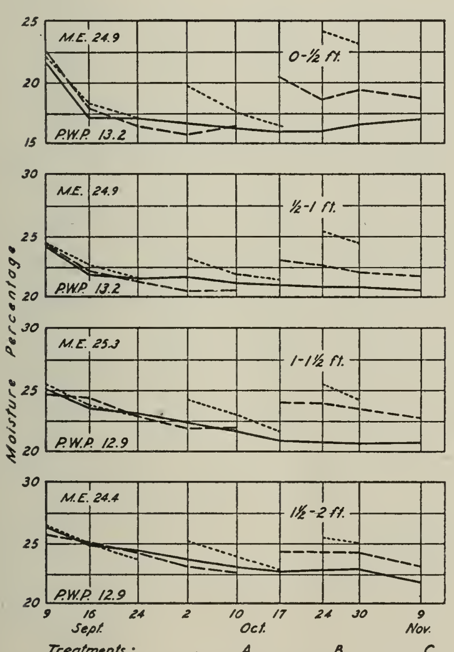


Fig. 23.—Soil-moisture conditions as determined by samples taken at the plant, Stirling, fall, 1940. M.E. and P.W.P. are the moisture equivalent and permanent wilting percentage for each plant.

Soil-moisture conditions and permanent wilting percentages are shown in figure 23. The latter percentages are those determined for the summer crop.

Soil-moisture conditions directly at the plant as compared with those at the center of the furrow are shown in figure 24. It should be remembered that in this experiment the soil surface at the plant, which is on the bed, is approximately 4 inches higher than in the bottom of the furrow.

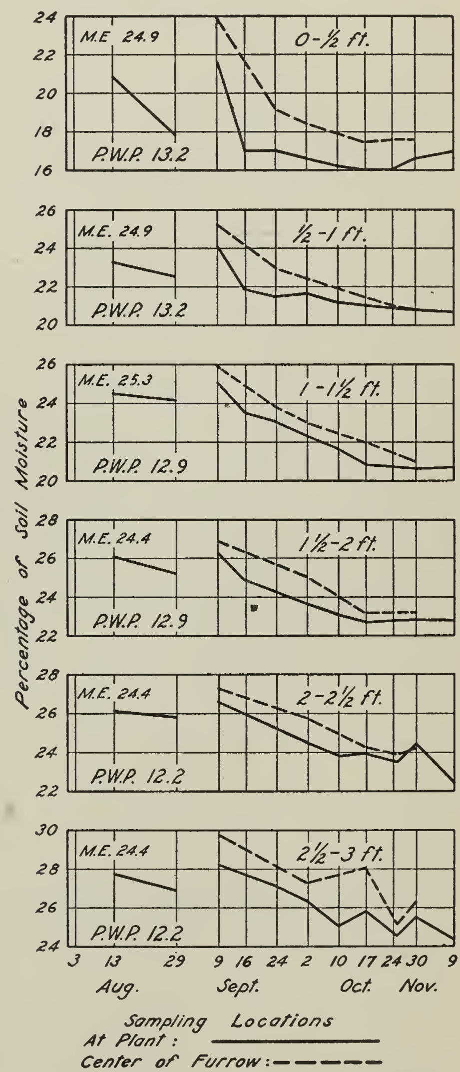


Fig. 24.—Soil-moisture records taken at the plant and at the center of the furrow, Stirling, fall, 1940.

Table 18: AVERAGE WEIGHT PER PLANT IN GRAMS, BASED ON SAMPLES OF 10 LETTUCE PLANTS PER PLOT, STIRLING, SALINAS, FALL 1940

Treatment	Plot	Dates sampled						
		Sept. 16	Sept. 24	Oct. 2	Oct. 9	Oct. 17[1]	Oct. 24[1]	Nov. 7, 9[2]
A	3	18	74	134	242	474	584	797
	6	17	49	120	208	379	616	808
	8	14	62	145	230	346	668	...
	12	14	75	113	258	376	583	717
	15	14	52	136	242	334	460	730
	19	14	37	128	195	334	460	679
	22	12	45	103	189	408	444	708
	25	10	34	82	196	320	525	685
	27	12	39	84	153	244	514	642
Average.	..	14	52	116	213	357±8.4	547±12.0	721
B	2	11	48	116	219	366	462	775
	4	15	65	159	266	450	673	778
	7	14	40	98	202	375	491	757
	10	18	64	158	239	475	516	763
	13	14	40	144	250	525	586	807
	17	14	51	156	291	456	569	796
	20	14	48	98	191	363	494	740
	21	14	48	106	171	299	583	737
	23	10	35	79	159	351	450	689
	28	11	30	68	188	273	389	636
Average.	..	13	47	118	218	393±10.1	521±12.7	748
C	1	14	35	106	159	382	501	826
	5	14	51	121	190	344	610	830
	9	16	64	150	321	500	630	767
	11	17	67	159	306	464	651	812
	14	14	50	149	236	410	709	838
	16	12	52	166	300	457	600	755
	18	13	34	93	210	365	304	727
	24	12	36	105	179	356	500	667
	26	12	37	127	194	307	509	821
	29	10	36	93	194	260	567	722
Average.	..	13	46	127	229	384±3.0	578±13.2	777

[1] Probable errors determined on weights of individual plants.
[2] Probable errors could not be obtained from the weights taken on Nov. 7 and 9.

Table 19: NUMBERS AND WEIGHTS OF PLANTS, STIRLING, SALINAS, FALL 1940

Treatment	Total plants	Average total weight per plant[1]	Lettuce per acre	Marketable heads	Average weight marketable trimmed heads[2]	Marketable lettuce per acre
		grams	pounds	per cent	grams	pounds
A........	1184	721±14.1	31,970	82.8	447±6.5	16,310±237
B........	1501	748± 8.4	33,030	84.5	468±5.6	17,410±209
C........	1482	777±10.1	34,300	90.6	476±6.3	19,000±252

[1] Probable errors based on average plant weights per plot for each treatment.
[2] Probable errors are based on the 10 plot average for each treatment. In all tables except tables 16 and 19 the probable errors for marketable heads are based on individual weights of heads.

Five cuttings to harvest the crop were made October 31, November 4, 8, 14, and 19.

Yields are shown in table 19.

The yield of marketable lettuce from treatment C is significantly larger than that from each of the other two treatments, and that from B is just significantly larger than from A.

On October 31, 10 untrimmed heads from 2 plots of A and 2 plots of C were harvested by cutting each head at the base of the lowest leaf. Moisture percentages on a fresh weight basis were then determined. The data gave an average percentage of 94.9 ± 0.4 for the 20 heads from A, and 95.9 ± 0.4 for C.

On November 1, 6 marketable trimmed heads from each plot of the A and C treatments (or 60 heads per treatment) were selected at random. Heads from each of these treatments were packed in 2 crates. These crates were iced and held in cold storage until November 12. This would be about the usual time of transit by rail. When they were opened the cut surface at the base of the heads from the C treatment showed a pinkish tinge whereas those from the A treatment lacked this tinge. Otherwise there was no distinguishable difference.

Tests for firmness and flavor likewise showed no differences.

On November 15, after the fourth cutting, the same procedure was followed on all treatments. When the crates were opened 10 days later there was no difference in the heads from the various treatments. The slight difference in color of the cut ends of the lettuce observed in the first test could not be detected in the second test.

MATURITY OF HEADS

The term maturity is used to mean the state of growth at which the plants become marketable, even though the plants are not physiologically mature.

It is important to know whether irrigation delays or advances the time of maturity or marketability. The mean period of maturity was calculated for the different treatments in each of the nine experiments. The mean period of maturity was determined by the following equation:

$$\text{Mean maturity} = \frac{(X_1 \times C_1) + (X_2 \times C_2) + (X_n \times C_n)}{\text{Total number of marketable heads}}$$

where X_1 = number of marketable heads obtained at first cutting
X_2 = number of marketable heads obtained at second cutting
X_n = number of marketable heads obtained at last cutting
C_1 = number of days between time of planting and first cutting
C_2 = number of days between time of planting and second cutting
C_n = number of days between time of planting and last cutting

Data for mean maturity are given in Table 20. They show there is very little difference in time of maturity between treatments. The differences are not great enough to indicate that the treatment has any effect on the time the lettuce reaches a marketable stage. The greatest difference was 2.4 days between the mean maturity of the A and C plots in the 1940 Stirling fall crop.

DISCUSSION OF IRRIGATION EXPERIMENTS

Root Distribution

In these experiments soil-moisture extraction curves indicate that roots of lettuce penetrate the soil and use some water to a depth of at least 2 feet. This does not mean, however, that the soil is completely permeated by roots as is the case with most of the crops previously studied (18).

Figure 18 shows that even after the plant is 79 days old and 35 days after the soil was wetted, there were appreciable amounts of readily available water still present in the soil, even in the surface 8 inches of soil. There was extreme variation, furthermore, in the amounts of water in the soil at this time. This indicates that the plant had a sparse root development which was unevenly distributed in the soil.

Strangely enough, the same kind of plants grown in cans in laboratory trials containing approximately 600 grams of soil seemed to have a uniform distribution of roots which dried the soil to the permanent wilting percentage throughout.

Further indication of uneven root distribution is shown in figure 24. This condition is typical of all the experiments. The amount of water used at the plant was quite different from that used 14 inches away until October 17 when the plant was nearly mature. After October 17, all of the moisture extraction curves became nearly horizontal. This may be due to cloudy weather. Standard atmometer data (table 21) indicate that evaporation conditions were low between October 22 and November 7, 1940.

Soil-Moisture Conditions

The differences in moisture contents of the various experiments, regardless of the frequency and time of irrigation, are not great. In no case was the average soil-

Table 20: NUMBER OF DAYS ELAPSING AFTER PLANTING BEFORE LETTUCE REACHES MEAN TIME OF MATURITY

Experimental plots	Treatment	Mean time of maturity (days after planting)	Experimental plots	Treatment	Mean time of maturity (days after planting)
Union Ice,	A	82.2	Rowe,	A	73.5
Summer	B	82.2	Summer	B	73.5
	C	81.6		C	73.3
	D	80.6			
			Rowe,	A	93.9
Union Ice,	A	81.7	Fall	B	94.8
Fall	A′	81.6		C	93.7
	C	81.6			
	D	81.5	Stirling,	A	79.3
			Summer	B	79.1
Gerrard,	A	78.5		C	79.1
Summer	B	77.8		D	77.9
	C	78.1			
			Stirling,	A	95.3
Gerrard,	A	78.9	Fall	B	95.2
Fall	B	78.9		C	92.9
	C	78.3			
Capitanich,	A	78.5			
Summer	B	79.1			
	C	79.0			
	D	78.5			

moisture condition reduced to the permanent wilting percentage in the 6-inch layers sampled. In four experiments, however, the moisture in the surface 6 inches was reduced to within 2 per cent of the permanent wilting percentage. Therefore, the time of reduction of growth in the least frequently irrigated plots as compared to that in the frequently irrigated plots cannot be related to the exhaustion of the soil-moisture content. The uneven distribution of the roots apparently is such that even samples close to the plant do not give an exact measure of the moisture content of the soil in contact with the roots. Certainly the differences found by sampling, in view of previous work on the effect of soil-moisture on plant growth, are not great enough to be the cause of the differences in growth and yields obtained in these experiments.

Bringing Water to the Plant

It seems that the roots of these lettuce plants did not extend themselves into moist soil as is usually the case with other plants, but that it is necessary to bring water to them by irrigating.

A similar result was reported by Work and Lewis (19) who explained the necessity for maintaining the soil at a high level in a pear orchard on a clay adobe soil on the basis that "The roots do not seem to occupy the entire soil mass," and that "The soil-moisture content of the soil in contact with the feeding roots may be at or near the permanent wilting percentage, while at the same time the moisture content at some distance, perhaps only a few centimeters away, may be much higher, thus allowing the average content for an ordinary soil sample to be well above the wilting percentage at the

Table 21. EVAPORATION FROM STANDARD ATMOMETERS ON LETTUCE IRRIGATION EXPERIMENTAL PLOTS IN CUBIC CENTIMETERS PER HOUR BETWEEN DATES, FOR BLACK AND WHITE ATMOMETERS

Union Ice—Watsonville, 1938

Date	June			July				August			September			October	
	6	14	24	7	15	23	30	4	19	31	6	19	29	7	21
Black......	..	1.28	1.53	1.15	1.28	1.09	1.61	1.98	1.24	1.54	1.45	1.09	1.01	.96	.84
White......	..	.89	.94	.72	..	.69	.97	1.32	1.04	1.00	.61	.62	.64	.51	.54

Capitanich—Watsonville, 1939

Date	March	April				June				July		
	28	4	11	18	25	6	13	19	28	8	17	28
Black........	..	1.03	1.56	1.04	1.02	..	1.03	1.99	1.44	1.41	..	1.47
White.......	..	.76	1.11	.71	.71	..	1.22	1.29	.88	.79	..	.97

Rowe—Watsonville, 1939

Date	August		September				October				November	
	14	24	6	14	19	26	9	16	23	30	6	17
Black........	..	1.30	1.69	1.22	2.64	2.46	1.26	1.67	1.58	1.53	.96	1.04
White.......	..	.89	1.19	.81	2.06	2.08	.89	1.19	..	1.27	.66	.77

Stirling—Salinas, 1940

Date	May				June			July	Sept.	October				November	
	2	12[1]	20	29	5	12	20	3[1]	23	2	10	17	22	7	16
Black......	..	1.60	1.82	1.66	2.17	1.57	1.89	1.66	..	1.74	1.51	1.52	1.61	.97	1.58
White......	..	1.60	1.49	1.56	1.99	1.29	1.61	1.51	..	1.62	1.39	1.42	1.50	.95	1.72

[1] Bottles ran dry before being refilled.

time the tree shows serious distress for water."

Method of Sampling

Our method of sampling was not precise enough to measure the actual moisture content of the soil in contact with the absorbing parts of the roots. The soil-moisture curves cannot be interpreted in the same way as in our previous studies on plant-soil-moisture relations. They do, however, serve as a basis for calculation of losses of moisture.

The very small amount of water taken by transpiration and the short time the plants were allowed to develop in relation to maturity; that is, to finish their complete cycle of growth, together with a sparsely developed root system, makes it impossible to use soil moisture records,

either as an indication of growth or availability of water.

The only criterion we find to be practical for the time to irrigate lettuce is the interval between applications.

Weights of Plants

Examination of the data on mean weights of plants reveals that if the plants were irrigated more than 30 days before the weights of plants were taken, in some cases, but not all, there are significant differences in weights. However, unless 30 days elapsed without irrigation there are no significant differences.

There are instances where significant differences were obtained, but they could not be accounted for by differences in irrigation treatments. They are probably due to inherent variability of the plots.

Thirty Days May Elapse Without Irrigation

We believe, therefore, that there is a period of 30 days which may elapse without irrigation or appreciable amounts of rain without adversely affecting the plants when grown under the conditions of these experiments.

A Seeming Exception

One instance which would seem to be an exception, but which actually is not, is that of the Rowe summer crop wherein a difference occurred in the weights of plants of the C treatment as compared to A and B. This took place on July 10, which was 31 days after irrigation of A and 39 days after irrigation of B.

It would seem unlikely that depression of growth could have occurred in one day, but since we did not have measurements on the thirtieth day, this cannot definitely be decided. A case where no differences were obtained, which could be related to the irrigation treatments, was the Stirling summer experiment of 1940.

Yields

The yields of pounds of marketable lettuce per acre for the treatment receiving the greatest number of irrigations, D, are highest in 1 out of 4 cases, but in 1 case they are lower than those from A which received the fewest irrigations. In 4 trials C received the second highest number of irrigations, while D was the most frequently irrigated.

But in the remaining 5 trials there was no D treatment, therefore C had the most number of irrigations.

The yields in pounds of marketable lettuce are greatest in C in 6 out of 9 experiments.

In 6 out of 8 experiments, yields from B are less than those from C. It should be noted that the interval between irrigations for B, with one exception, was greater than 30 days.

Yields from A are lowest in 7 out of 9 experiments but in one, A-1, which was essentially the same as A, the yield is not the lowest and, in fact, is greater than D.

In all of the experiments, more than 30 days elapsed between the last irrigation and the first cutting in A.

Yield Differences Are Mostly Negligible and Inconsistent

In many instances the differences in yields are negligible. Furthermore, they are inconsistent in that the most frequently irrigated treatments did not always produce the maximum yields. For instance, in the Stirling summer 1940 experiment, the yield from A is greater than from D. In fact, it would seem that the differences obtained are the result of normal variability in plot yields, except in some cases for A.

In the Stirling summer experiment there were 10 replications for each treatment.

Further evidence of variability in yields is that of treatments A and A-1 of the Union Ice fall 1938 experiment. While

the irrigation treatment was the same, the difference between the treatments is as great as the difference between A-1 and the other treatments.

Effect of the Number of Irrigations on Yields

The number of irrigations and amounts of water applied cannot be used as the only means for determining the effectiveness of irrigation on yields.

As mentioned before, the time elapsed between irrigations (30 days or more as was the case in treatment A) seemed to be the controlling factor affecting yields. This is especially true with plants having relatively shallow and sparsely developed root systems as in the case of lettuce. This statement as to the effect of interval between irrigations upon yields is based on the fact that the yields from treatment A are the lowest in so many of the experiments.

Effect of Irrigation on the Time of Marketability

It is claimed that some irrigations advance or delay the time at which heads become marketable.

Marketability is determined by size and firmness, and conditions affecting quality such as disease and shape.

An irrigation is frequently given within a few days before cutting in the belief that the addition of water at this time results in firm heads and an earlier cutting date.

The records of the dates of maturity (table 20) show that the differences are too small and not consistent enough to indicate that the treatments had any effect on the time the heads became marketable. The maximum difference was found to be 2.4 days.

The time to cut a crop depends upon the judgment of the individual grower and might vary as much as the 2.4 days.

Moisture Content and Keeping Qualities

The moisture content and the keeping qualities of the heads were determined at the time of harvest.

The results indicate that there are no marked differences which can be attributed to the differences in irrigation treatments.

Tests of quality were made by tasting in all experiments. This failed to show any marked differences.

Irrigation Close to Harvest

The belief that lettuce requires an irrigation close to harvest time to produce firm heads is without foundation since our experiments do not show any difference in moisture content of the heads from the various treatments, nor in firmness, as measured by hand pressure, visual condition, and packing house inspection.

Bolting and Tipburn

There were few cases of tipburn or bolting in any of the experiments.

Bolting (production of seed stalks) was noticeable in only the Rowe 1939 fall crop. In this case temperatures above 100° F occurred about 44 days after planting. The bolting appeared to be more prevalent in the B than in the A and C treatments which may account, in part, for the lower production of marketable lettuce as shown in table 14. In spite of the loss due to bolting, the B treatment yielded over 6½ tons per acre, or about 191 crates, of marketable lettuce.

Tipburn, like bolting, was not extensive enough to be a decisive factor in production in any of the experiments except on the Capitanich ranch. In this experiment, however, the occurrence of tipburn did not seem to be related to the differences in irrigation treatments.

Bolting and tipburn did not occur frequently enough during the experiments to give sufficient data to permit drawing

definite conclusions as to the effect of irrigation on these conditions. It seems that with the climatic and soil conditions of these experiments, and with the variations in irrigation practice, irrigation is not the causal factor for bolting and tipburn.

Water Losses

In general, the rates of use of moisture as shown by the slopes of the moisture-extraction curves are about the same regardless of the irrigation treatment.

The calculation of the water losses from the soil taken from the soil-moisture curves in treatment B of each experiment shows that from 1.75 to 5.61 inches of water were taken from the soil by transpiration, evaporation, and drainage (table 22).

Drainage and evaporation directly from the soil surface probably account for a large portion of the losses, and transpiration must have been very small. These amounts are small in relation to those applied. For instance, the average total amount of water used for the summer in the frequently irrigated plots is 14.1 inches, and for the fall crops, 14.3 inches (table 23).

The average losses of water from the soil, on the other hand, for the B treatments in the summer crops, are 3.95 inches and for the fall crops, 3.16 inches.

The amounts of water applied, furthermore, are much less than those generally used in commercial practice.

Measurements of Water

Measurements of water applied to commercial lettuce fields are subject to considerable error. One pumping plant generally supplies water to crops in different stages of growth, and the individual attention necessary to segregate the use on the various portions of the field usually cannot be given.

Our measurements show that 6 to 10

Table 22: LOSSES OF SOIL MOISTURE AS INCHES OF WATER FROM TIME OF THINNING TO MATURITY*

Experiment		Depth of soil, feet						
		0–½	½–1	1–1½	1½–2	2–2½	2½–3	Total
	Summer							
Union Ice..	1938	1.34	1.30	.59	.19	..	..	3.42
Gerrard...	1938	1.15	1.42	.46	.42	.44	.0	3.89
Rowe.....	1939	1.27	.73	.76	.82	.89	.82	5.29
Capitanich.	1939	1.30	.89	.70	.31	..	..	3.20
Stirling....	1940	1.19	1.19	.85	.74	..	..	3.97
	Average	1.25	1.11	.67	.50	.66	.41	3.95
	Fall							
Union Ice..	1938	.48	.50	.32	.45	..	..	1.75
Gerrard...	1938	1.33	.28	.28	.38	..	..	2.27
Rowe.....	1939	1.46	.73	1.16	1.10	.79	.37	5.61
Stirling....	1940	1.13	.55	.43	.36	.28	.24	2.99
	Average	1.10	.51	.55	.57	.54	.31	3.16

* Extraction includes evaporation, drainage and transpiration as determined from soil-moisture records taken close to plants in the B treatments.

Table 23: INCHES OF WATER APPLIED ON IRRIGATION EXPERIMENTAL PLOTS

Experiment		Treatment				Water applied to most frequently irrigated treatment
		A	B	C	D	
	Summer					
Union Ice	1938	2.4	10.1	8.3	14.3	14.3
Gerrard	1938	10.0	13.8	19.0	....	19.0
Rowe	1939	15.3	13.4	16.0	....	16.0
Capitanich	1939	7.7	10.8	10.8	11.9	11.9
Stirling	1940	.0	2.0	4.1	9.4	9.4
	Average	7.1	10.0	11.6	11.9	14.1
	Fall					
Union Ice	1938	6.2	....	8.6	9.3	9.3
Gerrard	1938	8.0	9.9	14.9	....	14.9
Rowe	1939	15.8	17.8	18.4	....	18.4
Stirling	1940	6.9	9.9	14.7	....	14.7
	Average	9.2	12.5	14.2	9.3	14.3

inches were usually applied to germinate the seed. Much greater applications have been measured. In one case as many as 26 inches were applied. In this case, the runs were excessively long and the soil was highly permeable.

At the time of thinning from 4 to 6 inches of water are usually applied. Excessive applications have also been measured at this time. A measurement of 11 inches was taken on one field. Commonly, the applications following thinning are from 2 to 4 inches.

It is obvious that much water is wasted by deep percolation in growing lettuce. The presence of free water at depths of 6 feet or less is frequent in these lettuce growing areas and may be an indication of excessive use of water.

Flooding

In the experiments where the beds were flooded, the heads appeared to be as firm as when the beds were not flooded. Also, there was no difference in color or in the percentage of heads having butt slime. This does not mean that flooding may not be harmful from other considerations and under other conditions.

Height of Beds

The excessive amount of water used to germinate the seed is due in many instances to the use of high beds; for instance, those which are 6 inches or more in height. High beds are necessary, of course, on land not properly leveled.

Water must be kept in the furrows until the soil around the seed is moistened. The greater the distance the seed is above the water level in the furrow, the longer will be the time required to wet the soil around it.

In an experiment on a sandy soil, lettuce was grown on 24 low beds to serve as a comparison to adjoining high-bed plantings. The low beds were made by driving a broad-track tractor over the furrows. This made the furrows broad, shallow, and compacted instead of narrow, deep, and loose.

The amount of water needed to wet

the beds to germinate the seed was 11 inches for the low beds and 26 inches for the high beds.

In the case of the low beds, the furrows were completely filled and water partially flooded the beds. No dependence was placed on capillarity to wet the soil around the seed.

Both applications were excessive due to the highly pervious nature of the sandy soil and to the unevenness of the grade.

A second irrigation was made 44 days later. Eight and 11 inches were used for the low beds and high beds respectively.

These measurements show considerable saving in water when low beds are used.

Shortly before the second irrigation, a side dressing of fertilizer containing 30 pounds of nitrogen per acre in the form of nitrate was applied to the sides of the furrow, and the low beds flooded. Not long after this the plants in the low beds appeared smaller and yellower than those in the high beds. They were poorest in areas of the plot where greatest leaching of the fertilizer took place.

It should be remembered that a bed need not be any higher than is necessary to compensate for the unevenness of the land. It should also be high enough to prevent it from being flooded in cases where flooding should be avoided; for instance, when crusting of the soil surface occurs and interferes with seed emergence or where leaching is excessive. In this regard, when fertilizer is used it should be placed high enough on the shoulder of the bed to prevent leaching.

Crop Water Needs

Even though it has been shown that only about 4 inches of water are required for evaporation, transpiration, and drainage, it must not be assumed that this amount is all that is required to produce a crop of lettuce in the Monterey Bay region, because there is an inevitable waste in applying water.

As pointed out previously, large amounts of water are wasted in wetting the beds for seed germination, especially with high beds. Furthermore, the irrigation at thinning is applied only to wet a shallow layer of soil at the surface at a time when transpiration has only begun.

Four to 6 inches of water at planting, and 3 to 4 inches for the other two irrigations, or a total of 10 to 14 inches should be enough under good irrigation practice, and with well-leveled land, for summer and fall crops.

Data Provide Basis for Satisfactory Irrigation Schedule

The results of these experiments furnish data which may be used as a basis for a satisfactory irrigation schedule for summer and fall lettuce in the Monterey Bay region of California.

After the beds are prepared and seeded, and the land is in shape for irrigation, the first irrigation seems to be justified because the soil at this time is generally too dry for seed germination.

The irrigation which is usually given just before or just after thinning may be necessary even though there may be ample water in the soil at this time.

After the second irrigation, the third irrigation may be delayed for 30 days.

Three irrigations will be enough for the strains of lettuce grown under the conditions of our experiments if applied at the above stated times.

We believe that these recommendations can be made without loss of yield or quality.

CULTIVATION EXPERIMENTS

Five lettuce cultivation experiments were conducted in the Pajaro Valley (figure 1). These were carried out on a summer and fall crop in 1937, a fall crop in 1938, and spring crops in 1939 and 1940.

Plots were selected in commercial fields, and with the exception of the number of cultivations after the field was planted, they received the same cultural practices as did the remainder of the field.

A brief description of the general cultivation practices has already been given.

In every experiment there were two treatments.

One set of plots received the same number of cultivations as practiced by the grower.

The second set was cultivated only for the control of weeds. This resulted in a considerably larger number of cultivations for the first set.

In the first 3 experiments, yields were obtained by counting the number of packed, marketable heads from each plot. The heads were packed by commercial shippers.

In the last 2 experiments yields were obtained by trimming and weighing each marketable head.

DESCRIPTIONS OF THE CULTIVATION EXPERIMENTS

The five cultivation experiments were designated as:

1. Randolph, Summer, 1937.
2. Randolph, Fall, 1937.
3. Capitanich, Fall, 1938.
4. Loveless, Spring, 1939.
5. Loveless, Spring, 1940.

The above names are those of the ranches on which the experiments were conducted.

Randolph, Summer, 1937

Four plots, A, B, C, and D, of 4 beds each 1100 feet long were selected.

The soil is classed as a Metz fine sandy loam.

A and C received 4 cultivations.

B and D were given only 2 cultivations.

A chronological list of cultural practices follows:

April 18—Planted to strain 615-x and irrigated.

May 3—All plots cultivated on beds with weed-cutting knives and with chisels in the furrows.

May 10—Thinned.

May 26—All plots irrigated.

June 4—All plots cultivated with side knives and chisels on beds and in furrows, then hoed for weeds.

June 12—All plots irrigated.

June 14—Differential treatment started. Knives used on ridge and in furrow of Plots A and C.

June 18—Furrow and side knives used on Plots A and C.

Table 24: NUMBER OF LETTUCE HEADS PER PLOT PACKED FOR SHIPPING, RANDOLPH, WATSONVILLE, SUMMER CULTIVATION, 1937

Plot	Size as represented in heads per crate		Total
	60	75	
4 Cultivations			
A.........	1046	352	1398
C.........	991	357	1348
Total....	2037	709	2746
2 Cultivations			
B.........	860	498	1358
D.........	975	445	1420
Total....	1835	943	2778

June 22—All plots irrigated.
July 1—First cutting.
July 6—Second cutting.
Rainfall Record—.4 inch rainfall April 26 to 28. .17 inch rainfall May 18.

Yields are given in table 24, the data being secured from the two center beds of each plot.

Randolph, Fall, 1937

This experiment was conducted on a field different to the one used in the summer experiment.

The soil was very much the same as the soil in the summer experiment.

Four beds, 1100 feet long, were selected. These were bounded on either side by four additional beds which were cultivated 3 times.

Yields were obtained from the two center beds of the plots cultivated 3 times.

Two plots were made from the 4 beds cultivated 6 times.

The four plots were numbered in consecutive order, thereby making plots A and D those which were cultivated 3 times, and plots B and C those cultivated 6 times.

Weeds were quite prevalent on the plots cultivated only 3 times, and they became quite weedy just before cutting.

Cultivation practices in chronological order follow:

July 16—Planted to strain 515-x and irrigated.
July 30—Cultivated bottom of furrows with chisels.
July 31—Top of beds rolled.
Aug. 5—Disked top of beds and used side knives.
Aug. 9—Thinned.
Aug. 10—Applied 300 lbs. of 12-6-4 mixed fertilizer per acre.
Aug. 11—Furrowed out after thinning.
Aug. 16—Irrigated. Differential treatment started.
Aug. 23—Plots B and C cultivated on beds and furrows with knives and chisels.
Aug. 29—Hoed weeds from all plots.

Table 25: NUMBER OF LETTUCE HEADS PER PLOT PACKED FOR SHIPPING, RANDOLPH, WATSONVILLE, FALL CULTIVATION, 1937

Plot	Size as represented in heads per crate		Total
	60	75	
6 Cultivations			
B	1818	238	2056
C	1378	75	1453
Total	3196	323	3509
3 Cultivations			
A	1446	75	1521
D	1696	75	1771
Total	3142	150	3292

Chiseled top of beds and furrowed out on Plots B and C.
Sept. 1—Irrigated.
Sept. 7—Cultivated furrows with chisels on Plots B and C.
Sept. 14—Irrigated.
Sept. 24—First cutting.
Sept. 30—Second cutting.
Oct. 6—Third cutting.
Rainfall Record—.09 inch rainfall October 2.

Yields in number of packed commercial heads are shown in table 25.

Capitanich, Fall, 1938

In this experiment the soil is classified as a Botella silty clay loam, and is quite heavy.

Four adjacent plots 150 feet long, separated by guard beds, were used.

Plot A had two experimental beds. B had three. C and D each had four.

A and C were cultivated 4 times. B and D were cultivated once.

Table 26: CRATES OF LETTUCE PER ACRE BY PLOT AND BY TREATMENT, CAPITANICH, WATSONVILLE, FALL CULTIVATION, 1938

Plot	Total marketable heads per plot	Size as represented in heads per crate			Total
		48	60	75	
		4 Cultivations			
A	182	21.4	140.3	21.0	182.7
C	486	35.2	119.0	17.5	171.8
Average	...	31.7	124.4	18.4	174.5
		1 Cultivation			
B	405	41.9	136.5	10.9	189.3
D	353	21.1	112.6	12 9	146.6
Average	...	31.0	123.9	11.9	166.9

Table 27: AVERAGE WEIGHT IN GRAMS BY SIZES OF COMMERCIAL LETTUCE HEADS CUT AT FIRST CUTTING, CAPITANICH, WATSONVILLE, FALL CULTIVATION, 1938

Plot	4 doz. size		5 doz. size		6 doz. size		Totals	
	No. heads	Average weight grams	No. heads	Average weight grams	No. heads	Average weight grams	No. heads	Average weight grams
				4 Cultivations				
A	16	680	57	579	7	477	80	590
C	75	703	178	577	20	497	273	606
Totals	91	699	235	578	27	492	353	602
				1 Cultivation				
B	50	707	129	601	4	490	183	627
D	32	806	138	592	7	497	177	627
Totals	82	745	267	596	11	494	360	627

A chronological list of cultural practices follows:

July 22—Planted to strain 847 and irrigated.

July 29—All plots ring rolled.

Aug. 14—All plots irrigated.

Aug. 18—All plots thinned.

Aug. 20—All plots cultivated on ridges and in furrows with knives and chisels.

Aug. 23—Side dressing of commercial fertilizer applied to all plots.

Aug. 25—All plots irrigated. Differential practice begun.

Sept. 2—Cultivated ridge and beds on plots A and C with chisels.

Sept. 5—Cultivated ridge and beds on plots A and C with chisels.

Sept. 12—Chiseled and furrowed ditches on plots A and C.

Sept. 17—Irrigated all plots.

Oct. 5—First cutting on all plots.

Oct. 10—Second cutting on all plots.

Oct. 13—Third cutting on all plots.

Rainfall record—.75 inch rainfall October 2.

Yields are shown in table 26.

Table 28: CULTURAL PRACTICES AND RAINFALL ON LETTUCE, LOVELESS, WATSONVILLE, SPRING CULTIVATION, 1939

Date	Rainfall, inches	Cultural practices	
1938			
Dec. 6	....	Fertilized with 2½ tons chicken manure.	
12	....	Planted to strain 615 lettuce.	
1939			
Jan. 16	....	Cultivated beds and furrows with knives and chisels.	
25	....	Thinned.	
27	....	Cultivated with knives, chisels, and mulcher, and applied 250 lbs. fertilizer 12–10–7.	
Feb. 8–11	1.08	Intermittent showers.	
		A Treatment	B Treatment
21	....	Cultivated ridge and furrows with knives and chisels.	
23	....	Hoed weeds by hand.	Scraped weeds by hand.
Mar. 1	....	Cultivated ridge and furrows with knives and chisels.	
4–14	2.45	Intermittent showers.	
14	....	Hoed weeds by hand.	Scraped weeds by hand.
20	....	Cultivated beds and furrows with knives and chisels.	
25–26	.50		
29	....	Cultivated beds and furrows with knives and chisels.	
April 1	.41		
4	....		Scraped weeds by hand.
12	.09		
19	....	First cutting.	First cutting.
24	....	Second cutting.	Second cutting.
28	....	Third and last cutting.	Third and last cutting.

Table 27 gives the average weights of marketable heads at the first cutting. The data show that yields based on the number of heads per packed crate are in close relation to the weights of the heads. Either method may then be considered a satisfactory basis for determining yields.

Loveless Experiments, Spring 1939 and 1940

The procedure in these experiments was different.

In the plots of the B treatment weeds were kept down by carefully scraping them with a sharp hoe with as little disturbance of the soil as possible.

Loveless, 1939

This experiment was made on a soil classed as a Pinto loam which cracks very little but becomes hard when dry.

In the 2 treatments, each having 12 plots, A received 6 cultivations and B received two.

Each plot comprised one bed 35 feet long with guard beds on each side. Beds were spaced 42 inches apart.

Cultivation practices and the rainfall record are shown in table 28.

Yields are shown in table 29.

Loveless, 1940

This experiment was conducted on a more fertile soil than that in the 1939 experiment.

The arrangement of plots was similar to the 1939 experiment, but the plots were 25 instead of 35 feet long.

Cultural practices and the rainfall record are shown in table 30.

Yields from this spring cultivation are shown in table 31.

Table 29: YIELDS OF LETTUCE, LOVELESS, WATSONVILLE, SPRING CULTIVATION, 1939

A treatment (Cultivated 6 times)				B treatment (Cultivated 2 times and weeds scraped)			
Plot	Total plants	Total marketable heads	Average weight marketable head[1]	Plot	Total plants	Total marketable heads	Average weight marketable head[1]
			grams				grams
1	70	60	551	2	64	56	585
3	67	50	520	4	65	59	648
5	68	60	552	6	63	53	561
7	58	56	563	8	67	61	536
9	69	54	470	10	67	56	521
11	66	61	529	12	60	49	487
13	62	56	593	14	66	52	465
15	68	59	560	16	62	55	588
17	61	49	591	18	60	48	612
19	62	46	573	20	55	39	576
21	55	45	612	22	67	51	637
23	60	47	528	24	59	46	659
	766	643	552±7.5		755	625	581±12.2

[1] Probable error is based on mean weight of marketable heads per plot.

Table 30: CULTURAL PRACTICES AND RAINFALL ON LETTUCE, LOVELESS, WATSONVILLE, SPRING CULTIVATION, 1940

Date	Rainfall, inches	Cultural practices	
1939			
Dec.	....	Field listed for planting	
11	.70		
15	....	260 lbs. fertilizer 11–11–0 applied on beds.	
20	....	Planted to Imperial 615 strain seed.	
24 to Feb. 7, 1940	15.68	Intermittent showers.	
		Differential Treatment	
1940		A Treatment	B Treatment
Feb. 13	....	Thinned and cultivated beds and furrows with knives and chisels.	Thinned.
14–28	6.32	Intermittent showers.	
Mar. 7	....	Cultivated beds and furrows with knives and chisels.	Applied 250 lbs. 10–7–14.
9	....	Applied 250 lbs. per acre of 10–7–14.	
12	....	Cultivated beds and furrows with knives and chisels.	
Mar. 16 to Apr. 8	4.16	Intermittent showers.	
Apr. 16	....	First cutting.	First cutting.
19	....	Second cutting.	Second cutting.
22	....	Third cutting.	Third cutting.
26	.48		
29	....	Fourth cutting.	Fourth cutting.

Table 31: YIELDS OF LETTUCE, LOVELESS, WATSONVILLE, SPRING CULTIVATION, 1940

A treatment (Cultivated 3 times)				B treatment (No cultivation)			
Plot	Total plants	Total marketable heads	Average weight marketable head[1]	Plot	Total plants	Total marketable heads	Average weight marketable head[1]
			grams				grams
1	41	29	402	2	41	39	431
3	50	47	423	4	38	38	415
5	40	38	426	6	54	50	441
7	51	49	425	8	43	41	429
9	46	44	441	10	47	46	518
11	47	45	450	12	44	43	413
13	48	43	424	14	44	43	428
15	42	36	418	16	42	40	403
17	50	46	410	18	46	44	401
19	44	37	365	20	38	34	399
21	32	28	380	22	34	34	432
23	31	27	392	24	41	40	403
	522	479	416 ± 4.7		512	492	428 ± 7.3

[1] Probable error is based on mean weight of marketable heads per plot.

DISCUSSION OF CULTIVATION EXPERIMENTS

Lettuce is a crop which has long received frequent cultivations. That some of this work may be saved is indicated by the results of these experiments on plots which were cultivated only for the control of weeds; or which were not cultivated after thinning but on which weeds were destroyed by scraping. This practice produced comparable yields to the frequently cultivated plots. Since cultivation does not save water in the absence of weed growth (16) it is clear that the primary purpose of cultivation after the crop is planted is to control weeds, and that cultivation of lettuce in the absence of weeds is wasted effort.

SUMMARY

Readily Available Water

The roots of lettuce plants under the conditions of these experiments penetrate the soil to a depth of at least 2 feet.

The soil is not thoroughly permeated by the roots of lettuce as is the case with most other crops investigated. For this reason, it is impossible to determine when the soil moisture in contact with the roots reaches the permanent wilting percentage.

The moisture content of the soil in contact with the roots may be reduced to the permanent wilting percentage, but that taken in the soil tube may contain some soil in which there are no roots, and the average moisture content of the sample would be higher than the permanent wilting percentage indicating that water is available to the plant; but this may not be the case. Furthermore, the very small amount of water taken by transpiration and the short time the plants were allowed to develop in relation to maturity added further difficulties in the interpretation of the soil-moisture data.

Soil-moisture records cannot be used as bases to determine when to irrigate lettuce. They are, however, the bases for determining the use of water.

Losses of Water

The loss of water from the soil by evaporation, transpiration, and drainage for any one crop amounted to a depth of water which may be equivalent to a rainfall of from 1.75 to 5.61 inches.

The amount of water taken from the soil by evaporation, transpiration, and drainage, averaging 3.95 inches for a summer crop, and 3.16 inches for a fall crop, is surprisingly small when compared to the amounts of water applied in commercial practice.

It should also be remembered that much water may be saved in using low beds.

Flooding

Flooding the beds did not reduce the firmness of the heads. In some cases, however, if the water is allowed to flood over the beds, detrimental conditions may result, especially from excessive leaching.

Differences in Weights of Plants and Marketable Lettuce

Decisive differences in weights of plants and marketable lettuce in the frequently and infrequently irrigated plots were obtained in most of the cases when the interval between irrigations exceeded 30 days.

Frequency of Irrigation

Irrigation need not be more frequent than once every 30 days after thinning, and under good irrigation practice, a total of about 14 inches should be ample to produce a summer or fall crop.

Time of Marketability

The time at which the heads became marketable was neither advanced nor delayed by the different irrigation treatments in these experiments.

The firmness of the heads, their moisture content, and their apparent eating quality also were not changed.

Keeping quality showed no differences which could be attributed to the differences in irrigation.

Bolting and Tipburn

Irrigation is not the causal factor for bolting and tipburn under the conditions of these experiments.

Yield Differences

There were no real differences in yield on the frequently cultivated plots compared to plots cultivated only to control weeds.

Recommendations

Results of these experiments warrant the following recommendations: that summer and fall-maturing lettuce in the Monterey Bay region be irrigated three times—to germinate the seed, at the time of thinning, and 30 days thereafter.

It is also recommended that cultivations after planting be limited in number and depth only to control weeds.

ACKNOWLEDGEMENT: The assistance rendered by Henry Washburn and A. A. Tavernetti throughout the course of these experiments is gratefully acknowledged.

Literature Cited

1. Andersen, E. M.
   1946. Tipburn of lettuce. New York Agr. Exp. Sta. Bul. **829**:1–14.

2. Dearborn, R. B., and J. R. Hepler
   1932. Head lettuce in New Hampshire. New Hampshire Agr. Exp. Sta. Cir. **39**:1–7.

3. Doneen, L. D.
   1947. Seed-bed preparation and cultivation for sugar beets. California Agr. Exp. Sta. Cir. **701**:1–16.

4. Doneen, L. D.
   1942. Some soil-moisture conditions in relation to growth and nutrition of the sugar beet plant. Ann. Amer. Soc. Sugar Beet Tech., pp. 54–62.

5. Hendrickson, A. H., and F. J. Veihmeyer
   1942. Irrigation experiments with pears and apples. California Agr. Exp. Sta. Bul. **667**:1–43.

6. Hendrickson, A. H., and F. J. Veihmeyer
   1942. Readily available soil moisture and sizes of fruits. Amer. Soc. Hort. Sci. Proc. **40**:13–18.

7. Hendrickson, A. H., and F. J. Veihmeyer
   1938. Responses of fruit trees to comparatively large amounts of available moisture. Amer. Soc. Hort. Sci. Proc. **35**:289–292.

8. Hendrickson, A. H., and F. J. Veihmeyer
   1946. Unnecessary irrigation as an added expense in the production of prunes. Amer. Soc. Hort. Sci. Proc. **48**:43–47.

9. Knott, J. E., E. M. Andersen, and R. D. Sweet
   1939. Problems in the production of iceberg lettuce in New York. New York Agr. Exp. Sta. Bul. **714**:1–17.

10. Knott, J. E., and A. A. Tavernetti
    1944. Production of head lettuce in California. California Agr. Exp. Sta. Cir. **128**:1–51.

11. MacGillivray, J. H., and L. D. Doneen
    1942. Soil moisture conditions as related to the irrigation of truck crops on mineral soils. Amer. Soc. Hort. Sci. Proc. **40**:483–492.

12. Pryor, D. E.
    1944. The big vein disease of lettuce in relation to soil moisture. Jour. Agr. Res. **68**(1):1–9.

13. Schwalen, H. C., and M. F. Wharton
    1930. Lettuce irrigation studies. Arizona Agr. Exp. Sta. Bul. **133**:463–517.

14. Thompson, H. C.
    1927. Experimental studies of cultivation of certain vegetable crops. New York Agr. Exp. Sta. Mem. **107**:1–73.

15. Thompson, H. C., P. H. Wessels, and H. S. Mills
    1931. Cultivation experiments on certain vegetable crops on Long Island. New York Agr. Exp. Sta. Bul. **521**:1–14.

16. Veihmeyer, F. J.
    1927. Some factors affecting the irrigation requirements of deciduous orchards. Hilgardia **2**:125–291.

17. Veihmeyer, F. J., and A. H. Hendrickson
    1943. Essentials of irrigation and cultivation of deciduous orchards. California Agr. Exp. Sta. Cir. **50**:1–23. Revised edition.

18. Veihmeyer, F. J., and A. H. Hendrickson
    1938. Soil moisture as an indication of root distribution in deciduous orchards. Plant Physiol. **13**(1):169–177.

19. Work, R. A., and M. R. Lewis
    1936. Relation of soil moisture to pear tree wilting in a heavy clay soil. Jour. Amer. Soc. Agron. **28**:124–134.

8½m-3,'49(B1387)

141